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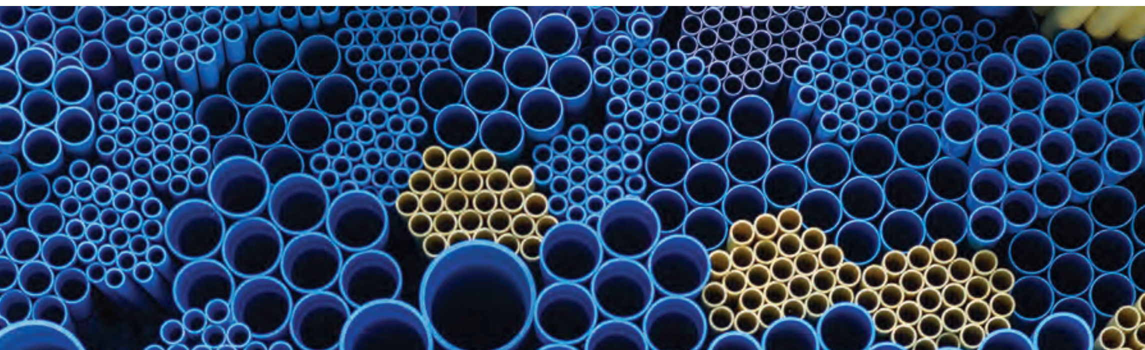
WATER INSECURITY AND SANITATION IN ASIA



Edited by Naoyuki Yoshino, Eduardo Araral, and KE Seetha Ram

ASIAN DEVELOPMENT BANK INSTITUTE

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Endorsement

I offer my congratulations to the Asian Development Bank Institute, the Lee Kuan Yew School of Public Policy, and all authors on their excellent volume comprising 18 chapters that examine various innovations in the water and sanitation sector in Asia.

The studies illustrate how water and sanitation infrastructure can generate positive spillover effects, such as reductions in morbidity from waterborne diseases and the appreciation of urban property values.

I sincerely hope that policy makers in Asia will consider the innovative approaches discussed in this volume to accelerate progress toward water security in the region.

Yoshiro Mori
Former Prime Minister of Japan
President, Asia-Pacific Water Forum

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The editors would like to thank all contributors to this edited volume for their insightful policy messages that can be used to help Asian countries achieve the Sustainable Development Goal target on water and sanitation.

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PART I

Introduction

1

Overview of Water Insecurity and Sanitation in Asia

Eduardo Araral, Naoyuki Yoshino, and KE Seetha Ram

As Asia rapidly urbanizes, providing water and sanitation services has become problematic. Most developing country governments in the region cannot deliver the required services themselves, and the private sector is reluctant to invest due to the risks and low returns, especially for sanitation. Public–private partnerships in water supply and sanitation have had mixed results, making sustainable sanitation a particularly challenging problem.

Fortunately, there are new and innovative ways to solve the problem of sustainable financing for water and sanitation services. One such innovative method, as demonstrated in some countries, is based on the idea that water and sanitation infrastructure generates positive spillover effects that can be captured and returned to investors to increase the rate of return and, hence, the incentive to invest. These positive spillover effects include a significant reduction in morbidity from water-borne diseases, more affordable water supply, increase in water consumption, and the appreciation of urban property values. The benefits of sanitation infrastructure are also significant and include reductions in diarrhea, cholera, typhoid, dysentery, and hepatitis, along with an increase in local economic development, a reduction in groundwater contamination, improvement in the recharge status of nearby aquifers, and economic benefits, such as the reuse of treated water for agriculture and/or industrial purposes and in terms of waste-to-energy benefits. Higher property values mean higher tax revenues, which can then be reinvested in other infrastructure, thus generating a virtuous cycle.

As a proof of concept, in this volume, Yoshino et al., in Chapter 3 estimate the spillover effects of the Southern Tagalog Arterial Road Expressway in the Philippines vis-à-vis the appreciation of property values. They estimate that the expressway increased property values on average by about twice as much compared to the period before its construction.

If policy makers were made aware of these spillover benefits, they would be able to devise tax policies to capture them and, in turn, use them for more sustainable financing for infrastructure.

This volume brings together 17 studies that examine various innovations in the water and sanitation sector in Asia and, most importantly, identify their spillover effects. This is the first attempt of its kind, and hopefully it will give budget-constrained policy makers incentives to introduce these innovative approaches to the sustainable financing of infrastructure in general, and water and sanitation in particular.

In Chapter 2, Kelkar and Seetha Ram review the literature on decentralized non-sewered sanitation, innovative implementation mechanisms, and socioeconomic spillover effects. They show that some developed Asian countries today invested in sanitation early on in their economic and infrastructure development despite the prohibitive cost of the related infrastructure and services. Subsequently, these countries experienced growth in the sector and increases in gross domestic product. They also point to innovative sanitation solutions, such as Japan's *johkasou* system or packaged wastewater treatment plants.

Along with Japan's networked systems in cities, rural areas, and independently owned houses, the *johkasou* system is implemented for sludge collection and wastewater treatment. This dual on- and off-site system has resulted in the effective provision of sanitation in Japan. To support this system, Japan has channeled resources from diverse avenues, such as national subsidies, local government bonds, and landowner and user charges and developed regulatory systems.

Another innovative example cited by Kelkar and Seetha Ram is the fecal sludge management (FSM) system of Dumaguete City in the Philippines. In the early 2000s, the city faced tremendous contamination from uncollected and untreated wastewater, leading to the pollution of the city's bay and groundwater. An FSM program was established in 2006 whereby the city invested $500,000 in an on-site septage treatment facility that resulted in significant improvements in health, the environment, and the economy.

The investments were fully recovered in 8 years through a tariff of $1 collected monthly from each household to enable the local government to empty the septic tanks every 5 years. Since recovering its initial investment, the treatment facility has been generating ongoing revenue for the city. The implementation of this project also has led to the overall economic growth of the city through industry, tourism, productivity, and increased property values. This points to the importance of political will to facilitate projects.

In Chapter 3, Yoshino, Nakahigashi, Abidhadjaev, and Xu illustrate an innovative methodology for estimating the spillover effects of a tollway project using the case of the Southern Tagalog Arterial Road (STAR) Tollway in Batangas, the Philippines. Using a difference-in-difference (DID) methodology, they compare the STAR project before and after construction and a counterfactual of beneficiary versus non-beneficiary groups. The differences before and after and for the beneficiary versus non-beneficiary groups are regarded as the treatment effect or impact of the project.

Using the DID method, Yoshino, Nakahigashi, Abidhadjaev, and Xu find a robust and statistically significant impact of the STAR Tollway on business and property taxes and regulatory fees in the cities and municipalities it traverses. The authors also find spillover effects on adjacent municipalities (the so-called "highway effect"). The case study concludes that infrastructure investments can play an indirect role in boosting tax and non-tax revenues. The same methodology can be applied to estimate the spillover effects of investments in water and sanitation that, in turn, could help make such investments more viable.

Chapters 4–12 examine country case studies from Bangladesh, India, Japan, Malaysia, Nepal, and the Philippines to illustrate successful sanitation interventions resulting in greater economic impacts.

Chapter 4, by Robbins, Seetha Ram, and Renzhi, provides a model and methodology to quantify the economic spillover effects of a citywide project in Dumaguete City in the Philippines and a pilot project in a district of Metro Manila. They conclude that by quantifying both the direct benefits for FSM (lower operation and maintenance costs) plus the spillover benefits (higher tax revenues, property values, and health outcomes), the overall project's economic viability can be made manifest.

In terms of the net present value of the project to the city's gross domestic product in the last 7 years, the estimates show that the Dumaguete City FSM project yielded benefits equivalent to 6.3 times the initial cost of capital investment. In terms of the net present value for new property taxes due to the FSM project, the ratio is 2.49. The payback period is 3 years, while the lagged effect of the investment—the time that the benefits are fully realized—is also 3 years.

Chapter 5, by Sogani and Vyas, documents the spillover effects of the Jaipur Sewerage Treatment Plant in India. These spillover effects include increases in property values, local business incomes and taxes, health impacts, loss of bad odor, and other social and environmental benefits. The study also includes the effects on groundwater contamination and the recharge status of nearby aquifers, and the economic benefits in terms of the agricultural and/or industrial reuse of treated water and in terms of waste-to-energy gains.

Sogani and Vyas report that overall, the sewerage project achieved its intended objectives. They note that there were no abnormal health issues, such as water-borne diseases (diarrhea) or infant and child mortality, after the project, and the nuisance of odor and high-potency wastewater was eliminated. As a result, more residential complexes were built in the area, and land prices increased by as much as 100 to 250 times in several areas. This trend subsequently brought huge infrastructure growth in the area. Moreover, the authors report that the treated wastewater is now discharged in colonies for agriculture, which has helped improve horticulture and revenues from farming. There has been an increase in employment opportunities and better development in the whole area. Sludge is also converted to biogas for electricity.

Chapter 6, by Gautam, Maurya, and Agrawal, provides a baseline study on drinking water quality, sanitation, and the hygiene status of selected public and private schools in Varanasi, India. The study examines the correlation between access to clean water and sanitation and the cognitive, creative, and social development of school children and gender parity. The study involved 14 Varanasi schools split equally between government and private types. Data were collected using questionnaires, key informant interviews, desk studies, and a qualitative analysis of drinking water. The findings are as follows. First, the total strength of teaching and/or nonteaching staff and boys' enrolment was significantly higher in private schools than government schools, whereas girls' enrolment was relatively higher in government schools. Second, the gender parity index in government and private schools was 0.76 and 0.64, respectively, meaning public schools pay more attention to gender parity. Third, government (57.1%) and private (85.7%) schools complied with the norm for the pupil–teacher ratio. Fourth, 85.7% of government and 71.4% of private schools followed the World Health Organization norm for drinking water points. Fifth, based on their physico-chemical and biological properties, drinking water samples collected from government and private schools fell under satisfactory and excellent categories, respectively. Sixth, a strong positive correlation was attained between students' enrolment and the availability of toilets in schools. Seventh, around 40% of government schools and 14% of private schools followed the students' toilet ratio for girls and boys. The study highlights the need for focusing on drinking water quality and the sanitation status of government schools to motivate local bodies, stakeholders, and school authorities to develop, organize, and maintain clean environments in schools and promote gender parity.

Chapter 7, by Shah, reports on innovative public–private practices in water and sanitation in India. These public–private partnership models focus on collaboration between communities, women, and implementing agencies to deliver safe drinking water and better sanitation and also to educate women on hygiene and personal well-being. Shah notes that the emphasis in recent years has shifted from longer-term contracts to shorter, more targeted, performance-based management. She also notes that monitoring compliance with these performance targets requires sound regulatory instruments that are made part of the system through greater accountability and clear delegation of responsibilities. Further, there is still a need for better financing options, but Shah argues that successful policy and reform implementation is possible through political facilitation. Overall, Shah reports that these projects not only have a positive impact on communities and beneficiaries but also improve industry productivity while reducing pollution. New local players are taking greater roles to monitor water usage and promote recycling in order to make more water available for agriculture and for meeting domestic demands.

Chapter 8, by Raina, Suwal, and Gurung, looks into the distributional implications of urban public water supply in Kathmandu, Nepal, by assessing how the socioeconomic status of a household affects access to the piped water network as well as the quantity and perceived quality of water. Using regression analyses of survey data on 1,500 households in 2014, Raina, Suwal, and Gurung find that poorer households had significantly less access to the public piped water network than richer households. Moreover, poorer households received lower volumes of water from the piped network connection than richer households, but there was no difference in terms of perceived water quality. The results of the study highlight the importance of paying attention to the distributional implications of the public water supply. While a water supply project could have positive spillover effects in terms of higher property values, higher tax collection, and better health outcomes, the distributional implications for rich and poor households should not be ignored.

In Chapter 9, Sarker and Yamashita present a spatial panel modelling (2009–2014) of water and sanitation insecurity using evidence from Bangladesh to draw policy implications for South Asia. Using fixed and random effects models with both spatially correlated error components and spatially lagged dependent variables, they analyze the determinants of drinking water and sanitation insecurity and disparities for the period 2009–2014.

In addition, Sarker and Yamashita focus on diagnostic testing procedures to decide how the spatial dependence is included in the models by using a Lagrange multiplier test. They also perform a Hausman test for two alternative hypotheses within the panel models for fixed and random effects in order to guard against local model misspecification. Their findings show a significant relationship between the insecurity of drinking water and sanitation and household size, literacy rate, child labor, access to mass media and information communication technology of young women, and the daily agricultural labor wage. In addition, a positive spatial correlation is found among the local distribution of the insecurity of the use of sanitation and water sources, but the strength of this spatial correlation varies considerably by spatial weight.

Chapter 10, by Lee, describes how the Republic of Korea, once an impoverished country and now one of the top 10 economies in the world, managed to overcome its water and sanitation challenges alongside the growth of its economy. As the economy grew and created a strong middle class, the demand for clean water and sanitation from households and industries kept pace with economic development, as predicted in the Kuznets curve.

As the economy rapidly developed, the government responded by building water supply infrastructure that had a positive and significant impact on the country. For example, in the Republic of Korea's early years of economic development, one unit of developed water resource led to a 0.577 unit increase in the country's gross domestic product. More recently, the Republic of Korea's water policy has focused on improving water quality, reducing pollution, achieving river restoration, and adapting to the effects of climate change.

Like most countries, the responsibility for water resource management in the Republic of Korea is divided among several government agencies. For example, the Ministry of Land Infrastructure and Transport is responsible for comprehensive water resource development, such as river, reservoir, and groundwater management and flood control. The Ministry of the Environment, on the other hand, is responsible for water conservation and the provision of local water management, re-use, and sewage systems, while the Ministry of Agriculture is responsible for agricultural water, such as irrigation canals, dams, and groundwater management. The Ministry of Energy is responsible for hydropower development.

Chapter 11, by Narayana, documents how Malaysia has achieved almost 100% access to toilets and safe sanitation in the last 50 years. Narayana reports that more than 70% of the population now has access to sewerage services that drain into offsite treatment facilities. Close to 20% use proper septic tanks, while the remainder use modified septic tanks or pour-flush or pit latrines. About 20%–30% of onsite facilities are regularly emptied and the sludge treated before disposal, while the rest are emptied upon request.

These results came about in large part because of Malaysia's rapid economic development and urbanization and the rise of privately developed housing estates. As Narayana documents, local governments required private housing developers to build internal sewerage infrastructure as part of property development and to rely on local governments, which had limited capacities. Smaller developments had to provide individual septic tanks to ensure that sewerage infrastructure was provided for all developments. The private sector led this approach to sanitation and, according to Narayana, helped to relieve the burden on the local government.

Private sector-led development, however, is not without its challenges. Narayana enumerates the challenges as follows: (1) a lack of standardization in design, systems, equipment, and arrangement; (2) some systems were defective in design, and local authorities lacked the technical personnel to manage them; (3) developers selected the lowest-cost options, which were often difficult to operate and maintain or had high operational and maintenance costs; (4) these facilities developed serious defects, and neighborhoods suffered overflows, odors, and nuisances; (5) the sewerage infrastructure soon began to crumble, and discharges and overflows of raw or poorly treated sewage were widespread; (6) septic tank numbers grew, and, because the accumulated sludge was not emptied regularly, sludge overflowed into drains; and (7) when these facilities were desludged, there was no proper treatment of the sludge; further, the sludge was often applied on land or discharged into the sea or rivers.

The Malaysian government took responsibility for sewerage services via the Sewerage Services Law in 1993, creating a regulatory department and privatizing sewerage collection under a 28-year concession agreement. Narayana reports that these changes led to "spectacular improvements in sewerage management. Unprecedented amounts of funds were invested for the repair, refurbishment, and upgrading of the dilapidated sewage treatment plants. Regulatory control was tightened." Moreover, "guidelines and standards were established, and a system to check and approve all new sewerage built by private developers was introduced. This resulted in a vast improvement in the quality of developer-built systems. The government … instituted training and capacity-building programs, and, over the years, many technical and managerial personnel were produced."

Chapter 12, by Hashimoto, describes how Japan's decentralized wastewater management system evolved over time. As in Malaysia, the key to Japan's success was the passage of a law in 1975 that ushered in the development of the wastewater industry through the training, development, and certification of 213,000 sanitation professionals. The industry evolved to set and enforce its standards and to introduce technological, organizational, and operational innovations over time. The development of the wastewater industry in turn was closely associated with Japan's rapid economic development that led to increased demand and capacity to pay for its services. Like Malaysia, the case of Japan highlights three lessons for developing countries. First, there is a need to establish a legal framework for the wastewater industry. Second, there is a need to train and certify the industry. Third, the development of the industry goes with the country's economic development.

Chapters 13–16 bring together country case studies on various policy perspectives on water and sanitation in Asia.

Chapter 13, by Gautam, reviews India's sanitation policy, that is, the Swachh Bharat Mission and its implementation in the states of Bihar and Jharkhand. India accounts for 60% of the number of people globally who defecate in the open. In 2014, the Government of India launched the Swachh Bharat Mission to tackle this problem. The initial implementation of the program points to a cosmetic understanding of behavior change that is needed to address the problem. Using academic and policy literature reviews and primary interviews with government officials implementing the Swachh Bharat Mission, Gautam finds evidence that increased latrine coverage does not necessarily improve health outcomes. Gautam recommends more focus on the behavioral aspects of the program, a review of performance indicators beyond the construction of toilet facilities, and more community participation.

Chapter 14, by Lakshmisha, Agarwal, and Nikam, focuses on water security in peri-urban areas in Bangalore, India. They argue that water resources that lie on the fringe of cities or the peri-urban area are the first casualty of urbanization, as they have multiple, contested uses. The consumption of resources by urban areas from their peripheries has resulted in the looming threat of conflict between urban and peri-urban areas. This, coupled with the changing climate, has impacted the availability, quantity, and quality of water resources, and has rendered the local communities vulnerable to water security. They note that jurisdictional ambiguity, lack of cooperation, and the absence of coordination among the various government bodies often result in uncertain actions among stakeholders.

The authors note that research on peri-urban areas in India is limited and concentrated on certain pockets. The chapter is based on a study of Bidadi, an industrial hub located in the periphery of Bangalore, that underscores the need for inclusive, collaborative, and participatory planning to achieve national and international goals, including the Sustainable Development Goals on water and sanitation.

Lakshmisha, Agarwal, and Nikam further employ a cognitive science approach to quantify perceptions, values, and subject knowledge attached to water resources by various stakeholders using fuzzy cognitive maps (FCMs). FCMs are a practical and potentially powerful tool used for anticipatory action research by incorporating multiple stressors for planning. Two hundred and forty FCMs were drawn up that capture stakeholders' behaviors related to how water security in their areas is impacted. In addition, household surveys and in-depth interviews with *gram panchayat* (village council) members and industrial representatives were used to collect data. Policy simulations also reveal that increased public–private partnerships through corporate social responsibility for water resource management and rainwater harvesting implementation tend to address the positive impact on participation management in a sustainable manner.

The authors' findings indicate that water insecurity in peri-urban areas is likely to be a function of high demand and the poor management and maintenance of water bodies, rather than absolute scarcity of water. Unplanned development has resulted in the neglect of natural resources, including water sources. Although the *gram panchayat* is blessed with adequate water sources, they are contaminated and not suitable for consumption. This impact has been aggravated due to climate change, mainly through variation in rainfall and temperature increases, resulting in the drying up of surface water bodies. The urbanization of Bengaluru and its peripheries has affected the quality of available water; although it has increased the financial capabilities of peri-urban communities, increased spending on drinking water has offset it. Lakshmisha, Agarwal, and Nikam conclude that the lack of property rights, lack of awareness, and heterogeneity has resulted in a weak institutional set-up with skewed interactions and communication between stakeholders.

Chapter 15, by Tiwari, highlights the institutional challenges of water and sanitation in India. For instance, some 600 million people face high-to-extreme water shortages, 75% of households do not have drinking water on the premises, 84% of rural households do not have access to piped water, and almost 70% of water is contaminated.

These challenges are exacerbated by India's water institutions existing in bureaucratic silos along the lines of state and/or center, surface water and/or groundwater, irrigation departments and/or water user associations, rural drinking water and/or irrigation, urban drinking water and/or industries, and many more. The lack of institutional capacity and resources (human and financial) has resulted in a dysfunctional water resource management system. The insensitivity of stakeholders toward water resources is leading to inefficient water use and mismanagement. If not addressed, water scarcity could pose a significant challenge for India's economic development.

Recognizing that the water problem in India is more an institutional issue than a technical issue, Tiwari's chapter analyzes the current and proposed arrangements for sustainable water resource management and examines the effectiveness and equitability of the legal framework. Tiwari points to two recent developments: the Draft Water Framework

Bill 2016 and the 21st Century Institutional Architecture for India's Water Reforms, which call for shifting away from current practices in water management.

For the management of water resources, Tiwari argues that the river basin states need to form authorities to plan water management at the basin level. On the other hand, the operation and maintenance of project assets and service delivery should be left to local institutions whose rights and obligations should be clearly specified. This would also require that the capacity and capabilities of the local-level agencies (such as municipalities, irrigation departments, pollution control boards, *panchayati raj* institutions, and water user associations) involved in the operation and management of water assets, service delivery, and monitoring of water resources are substantially strengthened.

To improve the water sector, the focus of resource development should shift to the better maintenance and upgrading of existing assets and small, decentralized, local augmentation projects involving water harvesting and watershed development. In the urban context, one way to improve service delivery is to enhance transparency and accountability through the "corporatization" of water utilities. For the management of industrial wastewater, Tiwari suggests a shift away from punitive legislation toward the appropriate pricing of water and incentive structures for the use of recycled water. For better decision making at all levels, he suggests that management information systems should be required.

Chapter 16, by Xenarios, Sehring, Assubayeva, Schmidt-Vogt, Abdullaev, and Araral, assesses water security in Central Asia. The authors argue that the idea of water security in Central Asia has been interpreted in a variety of ways through engineering, socioeconomic, geophysical, and integrated modelling approaches. They note that recently, there have been efforts to assess water security in the region by introducing different indicators and indexes, arguing that these new approaches represent water security in a fragmented manner, while the relevant indicators cannot fully attribute security status on a country or regional level. This can result in the misinterpretation of water security in policy dialogues and can also affect bilateral and multilateral relations in the region. The value added of their chapter is to identify the contribution of different approaches and indicators toward water security assessment in the region and how these are reflected in policy making. They use the water security framework from the Asian Development Bank's *Asian Water Development Outlook* as the basis for their assessment following five key dimensions: household, economic, urban, environmental, and resilience to water disasters.

Chapter 17, by Narayanan, highlights the need for decisive action to achieve water and sanitation security. Narayanan also refers to the important role of the Asia-Pacific Water Forum, an open platform that has brought together the formidable experience of developing water security available in the region by sharing information, knowledge, and experience, leading to decisive actions.

We conclude in Chapter 18 by drawing conclusions and offering some insights for a way forward for tackling water insecurity and sanitation in the region.

2

Literature Review Evaluating New Approaches to Resolving the Sanitation Challenge in Developing Asia

Vedanti Kelkar and KE Seetha Ram

2.1 Introduction

Water and sanitation are core targets of the Sustainable Development Goals (SDGs) and the United Nations' (UN) 2030 Agenda. SDG 6's focus on clean water and sanitation clearly outlines the urgent need to adapt and develop innovative solutions. Sanitation has been a consistently challenging development goal, with over 1.7 million people in the Asia and the Pacific having no access to safe sanitation, 780 million still practicing open defecation, and 80% of wastewater being disposed without appropriate treatment. As Asia is witnessing rapid urbanization, the provision of safe sanitation remains crucial. It is estimated that 57% of urban dwellers lack access to toilets that provide a full sanitation service chain, including containment, treatment, and end-use treatment and disposal (Asian Development Bank 2016a).

There are numerous socioeconomic and environmental benefits from improved sanitation, including a lower disease burden, improved nutrition, increased literacy and safety for girls and women, reduced stunting, improved quality of life, healthier living environments, increased job opportunities and wages, and improved regional competitiveness (World Bank 2007). Experts have unanimously emphasized the need to attract attention to the impacts of a lack of sanitation on a nation's gross domestic product (GDP). The idea that one dollar invested in sanitation can yield at least a fivefold return in increased productivity is representative of a larger potential economic impact in the case of countries such as Cambodia, Indonesia, the Philippines, and Viet Nam. In these countries, an estimated annual loss of $9 billion arising from poor sanitation equates to a 2% loss in GDP (World Bank 2007). A substantial part of these setbacks also arises from the resulting health-related economic impacts, such as was seen with the Ebola crisis in West Africa. Globally, poor sanitation resulted in a loss of about $222.9 billion in 2015, with Asia and the Pacific suffering the greatest losses at 1.1% of the region's total GDP, typically stemming from India and equaling almost 5.2% of the country's GDP (Lixil, Oxford Economics, and Water Aid 2016).

While studies on sanitation have focused on regions where it is persistently lacking, the resulting policy recommendations have not been successful in driving governments to prioritize improvements or investment. Globally, sanitation has consistently lagged water supply, but some Asian countries have shown remarkable progress with impressive coverage rates over the years. Specifically, Southeast Asia and East Asia have seen a marginal rise in basic sanitation services. Globally, from 2000 to 2015, basic sanitation increased by an annual incremental average of 0.63%. Southeast and East Asia's 77% coverage rate is significantly higher than Central and South Asia's rate of 50% (WHO and UNICEF 2017), but it was not always this high. In 1990, only 25% of Southeast Asia had access to improved sanitation, but access incrementally increased to more than 45% by 2012.

These developments indicate that sanitation improvements have gained substantial momentum in Southeast Asia and East Asia over the years. As Asia has rapidly progressed and urbanized over the past decade, countries in Southeast Asia and East Asia have been at the helm of economic development. As a result, the correlation between sanitation improvements and GDP growth has begun to attract attention.

While the literature has often described the lack of sanitation as a cause of losses that negatively impact GDP, the reverse has also been true. Countries such as Japan, the Republic of Korea, Malaysia, and Thailand are successful examples of governments that prioritized sanitation in the formative years of nation-building that contributed to GDP growth. While the authors do not intend to claim causality, they urge that a deeper understanding of the positive impact of sanitation improvements on GDP can shift points of view and perceptions of sanitation investments as an economic generation model as opposed to an economic drain.

Table 2.1 details the comparative sanitation coverage to GDP per capita scenarios of Japan, the Republic of Korea, and Thailand. Although the understanding of sanitation coverage is not universal, the numbers in Table 2.1 represent components such as latrine access, sewer network

Table 2.1: Comparative Sanitation Coverage and GDP per Capita of Japan, the Republic of Korea, and Thailand

	Japan[a]		Republic of Korea[b]		Thailand[c]	
Year	Sanitation Coverage (%)	GDP/ Capita ($)	Sanitation Coverage (%)	GDP/ Capita ($)	Sanitation Coverage (%)	GDP/ Capita ($)
1961	20	563.59	–	93.80	0	107.50
1966	48	1,058.50	–	133.45	5	161.00
1971	78	2,260.38	–	300.77	15	194.25
1976	89	5,171.04	–	830.70	34	391.48
1981	100	10,331.74	–	1,870.34	41	720.90
1986	100	17,079.60	–	2,803.37	45	813.20
1991	100	28,874.36	35.7	7,523.48	71	1,715.63
1996	100	38,436.93	52.6	13,137.90	97	3,042.90
2001	100	33,846.47	73.2	11,252.90	100	1,893.14
2006	100	35,433.99	85.5	20,888.38	100	3,368.95
2011	100	48,168.00	90.9	24,079.80	100	5,491.16

– = data not available, GDP = gross domestic product.

[a] Otaki, Otaki, and Sakura (2007).

[b] Korea Water and Wastewater Works Association (n.d.).

[c] Punpeng (2007).

Source: World Development Indicators.

coverage, and access to wastewater treatment in the form of overall sanitation coverage in the countries. Meanwhile, Table 2.2 describes the sanitary growth profile of only Malaysia through total latrine coverage and rural latrine coverage from 1961 to 2011.

In Thailand, where sanitation coverage grew from 41% in 1981 to 71% in 1991, and GDP per capita more than doubled during the same period, the country successfully achieved total sanitation coverage similar to the growth trajectory and the progress made by other developing countries of the time, such as Japan and the Republic of Korea. In the Republic of Korea and Malaysia, the governments also took strategic steps to achieve total sanitation, although the data are unavailable. In the Republic of Korea, the development of the country's water and sanitation sectors was consistently linked to economic growth. Additionally, when these countries first prioritized investments in sanitation, their GDPs were lower than those of sub-Saharan African countries, as shown in Table 2.3.

Developing Asian countries today resemble the GDP per capita of countries like the Republic of Korea and Malaysia from the 1960s,

Table 2.2: Malaysia's Sanitary Growth Profile

Year	GDP/ Capita ($)	Total Latrine Coverage (%)	Rural Latrine Coverage (%)
1961	234.92		12
1968		4.5	
1971	357.66	63.1	40
1981	1,774.74		80
1991	2,440.59		90
2001	4,045.17		98
2011	9,071.36		100

GDP = gross domestic product.

Source: World Development Indicators, Water Aid, UNDP Malaysia Country Team Report (2005).

Table 2.3: Progress of GDP to Sanitation Coverage

Country	GDP/Capita in 1960 ($)	Sanitation Coverage Rate in 2015 (%)
Republic of Korea	158.23	100.00
Ghana	182.97	14.28
Liberia	170.03	16.89
Senegal	247.23	48.00
Zambia	234.17	31.11
Zimbabwe	280.99	38.59

GDP = gross domestic product.

Source: WHO-JMP/World Bank Data, Water Aid (January 2018).

yet they have not been able to achieve comparative levels of sanitation coverage. For example, India's GDP per capita in 2018 was $1,977.29, but sanitation coverage was low. Following the implementation of the Swachh Bharat campaign, safe sanitation coverage in rural India has reached above 90%. In 1991, when Thailand's GDP per capita was $1,715.63, its total sanitation coverage was 71%, indicating that higher GDP per capita may not directly correlate and that countries that invested in sanitation improvements and succeeded in greater coverage were not as wealthy when they started.

It is important to understand that today's developing countries face increasing challenges and complexities with regard to urban sprawl, rapid urbanization, and the formation of informal settlements. It may be significant for sector experts to explore the idea that sanitation coverage may be linked to GDP growth and that a myriad of policy reforms are needed to engender a new way of thinking about sanitation improvements and economic prosperity. Another dimension to sanitation implementation involves donor aid, official development assistance (ODA), and their effective allocations. "Asian countries have been able to receive substantial donor aid to develop the Water, Sanitation and Hygiene (WASH) sector. ODA to countries like [the People's Republic of China], India, and Turkey consists of loans that have financial grants of at least 25%. Yet, sanitation and water consisted of only 1% of the GDP for the countries in 2008–2009" (OECD 2011). In the case of Indonesia, "2.3% of GDP was lost due to lack of sanitation which is 20 times higher than the required investments" (World Bank 2007).

2.2 Socioeconomic Spillover Effects from Improved Sanitation

Understanding the wider impact of aid disbursements is essential for cultivating the socioeconomic spillover effects from improved sanitation. Until now, the emphasis has been on the direct impacts from sanitation interventions; very few studies have documented the larger benefits that can be seen over a longer period in terms of higher literacy, better job opportunities, increased health and business opportunities, and all-round well-being. With development aid projects, negative outcomes related to community benefits and socioeconomic profits have resulted in a pessimistic atmosphere within donor agencies toward the continued success of investment in sanitation sector development and its impact on the end-use consumer. A study by Clarke, Feeny, and Donnelly (2014) argued that aid projects in the WASH sector should not only be assessed by their immediate benefit to their targeted communities but also by their lasting impact, that is, their sustainability. They found that although only 1 of the 27 examined water and sanitation projects in the Pacific countries could be considered sustainable through its direct impacts, the benefits from 22 projects persisted by way of enhanced community health. This reframing of the term "sustainability" to include persistent benefits can provide a more accurate assessment of an aid project's value.

Public investment portfolios assess projects based on their immediate impacts and full-cost recovery, but traditional measures

Box 2.1: The Case of the Dumaguete Fecal Sludge Management Plant

In early 2000, Dumaguete City in the Philippines faced tremendous contamination from uncollected and untreated wastewater leading to pollution of the city's bay and groundwater. A fecal sludge management (FSM) program was established in 2006 through which the city invested in a $500,000 on-site sewage treatment facility. Following deployment of the facility, the city witnessed improvements in health, the environment, and the economy. The investment was fully recovered in 8 years through a sewage tariff that consisted of each household paying $1 per month to the local government to empty the septic tanks every 5 years. Now that the initial investment has been recovered, the plant has been generating revenue for the city's employment program, infrastructure, health services, and education. The implementation of this project has also led to the overall economic growth of the city through growth in industries, tourism, livelihood, productivity and property values. The success of the Dumaguete FSM program has been documented extensively by the Asian Development Bank Institute (Robbins, Seetha Ram, and Renzhi 2019).

are unable to capture the wider impact of many projects, which can give them the false perception of failure. The above findings support our argument that while the immediate impacts from sanitation must be assessed, greater value from investment in the projects can be seen in the long-term spillovers, resulting in increased sustainability and returns from the investment through diverse avenues that, while not exactly associated with full-cost recovery, can provide larger benefits to governing bodies.

Therefore, the question remains why, despite receiving high ODA, countries in South Asia are unable to effectively prioritize and allocate financial resources toward improved sanitation.

For policy makers to view sanitation in the purview of economic development and specifically GDP growth, several innovative strategies are needed. The forthcoming sections of this chapter will analyze the components of the sanitation sector from a new perspective and present successful country cases. The overall motivation of the chapter is the redefinition of the way sanitation can contribute to economic development.

2.3 Literature Review

Developing Asian economies are facing complex challenges. The sanitation systems in rapidly urbanizing areas of economically progressive countries are beginning to crumble as they expand, resulting in inequalities in provision and regulation (Anderson, Dickin, and Rosemarin 2016). This literature review proposes a new way of thinking about sanitation by presenting historical trajectories, global scenarios, innovative system approaches through decentralization, current implementations, financing and revenue mechanisms, and political leadership as a catalyst to integrate processes.

2.3.1 Historical References of Sanitation Provision and Its Present-day Relevance

Throughout history, sanitation practices have evolved from place to place and within civilizations. From the Indus Valley, Mesopotamia, Babylon, and Greek civilizations to the Western Han Dynasty, domestic sanitation has been continually explored and innovated, from cesspools to disposal on unpaved streets and open pits, etc. (Cooper 2001). Acquiring water and addressing sanitation have been a continuous challenge. Following positive historical developments, sanitation implementation, especially in Europe after the collapse of the Roman Empire, underwent a dark period where the disposal of waste happened primarily on open streets (Cooper 2001). In other circumstances, "the improper disposal of human waste through groundwater led to devastating outbreaks of cholera and typhoid" (Domenech 2011; Geels 2005).

Historical data are a powerful tool for understanding the growth patterns of the sector and formulating informed decisions for the future. In this vein, Lofrano and Brown (2010) describe the evolution of wastewater management through the ages and its impacts on future policies. A key fact that emerges is that throughout history, while European cities were innovating and adapting new technologies to manage waste disposal, the direction was not always positive. According to Lofrano and Brown, toward the end of the 19th century, "only half of the Italian communities had access to drinking water and over 77% were not connected to any kind of sewers despite a previously well-developed sewer system" (Lofrano and Brown 2010: 5,258). Major changes were seen only at the end of the 19th century and at the beginning of the Industrial Revolution, when the significance of water and sanitation was understood for the economic and social development of communities.

To varying degrees, these circumstances reflect and resemble the situation witnessed over the past 3 decades in developing Asia. In the case of India, 80% of wastewater is disposed of without treatment and returns to the natural ecosystem of the oceans and other water bodies. This has enormous negative health and environment impacts, thus challenging the economic and social security of vulnerable populations.

2.3.2 Present Global Scenario: System Failures, Inability to Invest in the Sector, and the Unwillingness of Decision Makers to Make Changes

At present, Asia's developing economies have been adopting a centralized model of sanitation implementation focused on sewer networks. While this is the general scenario, there are exceptions. In India, only one-third of the population is connected to a sewer network. Many people use on-site systems in informal settlements and rural areas where the safe disposal and treatment of waste is costly and difficult, often leading to mismanagement and contamination of the surrounding areas. The concept of investing in wastewater treatment and other operation- and maintenance-related engagements has been conservative. Investment in small- and medium-size cities in middle- and low-income countries is a challenge due to lower revenues, whereas even in high-income countries like Sweden, smaller urban centers are closing treatment plants and building costly pipelines (Anderson, Dickin, and Rosemarin 2016).

Poor sanitation systems are particularly linked to institutional and governance failures (Araral and Yu 2013). For example, water and sanitation accounted for 8% in Asian Development Bank (ADB) assistance in 2017 in comparison to other sectors such as transport (27%) and energy (31%). The serious health risks related to open defecation and dysfunctional sanitation systems have not provided strong enough motivation for reform, and the lack of consumer knowledge extends beyond the health risks and includes the loss of environment and ecology from the contamination of groundwater by poorly disposed and untreated fecal sludge (Anderson, Dickin, and Rosemarin 2016).

Adequate funding for the comprehensive development of sanitation has been a constant challenge. This is coupled with issues related to the prioritization of the sector by central and provincial governments. As already discussed, historically, there has not been much focus on wastewater or fecal sludge management due to a lack of awareness of the benefits. The water supply sector, on the other hand, has consistently gathered more attention than the sanitation sector. With this understanding and knowledge, and for the holistic growth of sanitation provision, it is important to address the key issues faced by the sector. This involves a change in the perceived ideas of the best way to implement sanitation, either in networked or non-networked forms, and innovation toward more flexible approaches and greater technological know-how on innovative strategies, followed by the financial and profit mechanisms that help innovations thrive.

2.3.3 Decentralization, Technological Standardization, and Community Engagement

Until the 1990s, water supply was largely controlled by public organizations and municipalities (Domenech 2011; Kallis 2003), but in the past few years, water services around the world are gradually being privatized (Domenech 2011; Araral 2010). In terms of sanitation, the governance structure largely remains public due to the use of the centralized model associated with sewer network-based systems. However, this model is heavily cost-intensive and time-consuming due to its propensity to employ large-scale, city-wide sanitation projects. This implementation template has resulted in slow steps toward solving sanitation problems in comparison to the faster rate of urbanization and informal growth in developing Asian countries, leading to the use of unregulated, on-site collection and disposal techniques, especially in informal and peri-urban areas.

In the past decade, decentralized on-site sanitation measures have been increasingly adopted by private waste collection and disposal companies, nongovernment organizations (NGOs), and communities. Several small community- and town-level projects have been successful due to the use of decentralized mechanisms, despite inadequate state funding. It has been noted that the benefits of decentralization are far-reaching in terms of access to informal areas; the ability to make improvements as per local contexts; affordability due to low-cost, small-scale systems; and multi-stakeholder approaches.

Box 2.2: The Case of Japan's *Johkasou* System

In Japan, a combination approach has been administered to tackle sanitation provision effectively. Along with the networked system in cities, the *johkasou* (packaged wastewater treatment plant) system is implemented for sludge collection and wastewater treatment in rural areas and independently owned houses. Policies in Japan allocated financial resources and developed regulatory systems for system operation and maintenance. Through diverse avenues, such as national subsidies, local government bonds, and landowner and user charges, financial resources for the system's functioning and sustenance have been assembled. As in developing countries, Japan also faces challenges in securing land for sludge disposal and landfills, and usually transports sludge to treatment plants (Asian Development Bank 2016b).

Despite these successful examples, the governance and institutional and regulatory frameworks of decentralization have not been widely discussed or understood in the right spirit (see Araral [2009] for a review). One of the primary concerns to emerge from the application of decentralization is the variety of technologies and products available in the market. Several industries, research institutes, social innovators, and NGOs are developing non-networked sewer solutions. At fragmented levels, they are successful, but they fail to reach the wider realm of sanitation practice. Diversity of technology also leads to difficulty in comparison. The absence of a general standard for non-networked sanitation solutions has been a barrier for innovative solutions to enter the market (Starkl et al. 2015). ISO-30500, developed in 2018, provides specifications on general safety and performance requirements for design and testing as well as sustainability considerations for non-sewered sanitation systems (ISO 2018). The standard could help tackle the variety of technologies available on the market and, thereby, have systems that will satisfy the required health and environment indicators.

While standardization has been proposed for decentralized systems, it could also slow implementation and make existing applications redundant. Jack Sim, founder of the World Toilet Organization, expressed in a seminar at the Asian Development Bank Institute in July 2018 that a successful way to implement FSM and manage wastewater treatment was to allow stakeholders to implement the technology available to them, as opposed to introducing a standardized technology alien to the region. This may prove to be cost-effective and less time-consuming and give autonomy for more regionally contextual growth (Sim 2018). These discussions must be carried out at multiple levels within country contexts to create an ecosystem for all-around sanitation coverage.

As decentralization is followed by standardization, it is also followed by community engagement. Especially in the decentralized sanitation solutions market, social innovation has catalyzed ways to address problems. It is significant to understand that "social innovation is a key technology enabler [and] has also provided traction for the community to engage and cooperate with each other to implement effective solutions" (McGranahan and Miltin 2016). Further, the same study argues that "in deprived settings the key to sanitary improvements lies in meeting the institutional challenges posed by the need for local collective action, coproduction, affordability and housing security." Analyzing two successful community-driven projects—the Orangi Pilot Project and the Indian Alliance in Karachi and Mumbai—McGranahan and Miltin find that social innovation through technology can simplify sanitation solutions through low-cost products that, with the help of communities, can convince government officials and politicians to develop such projects.

Ultimately, to foster replicability and scalability, the implementation of decentralized approaches combined with evaluating the need for standardization and the inclusion of communities may prove to be an effective way forward.

2.3.4 Transformations in Innovative Financing Mechanisms for Decentralized Approaches, Hybrid Institutional, and Governance Structures

One often-stated concern regarding sanitation is the slow rate of return in related investments and the dependence on full-cost pricing through large-scale technological solutions. "The approaches by neo-classical economists in determining the revenue theories associated with sanitation have led to use of limited, high-cost intensive investment mechanisms making the sectoral investments complex. Their policies have largely focused on service provision from the government, financing services through user charges, and not from tax revenues and full-cost recovery based on the user pays principle" (Abeysuriya, Mitchell, and Willetts 2008). These findings strongly support our argument on multiple levels: that the broader ideological inclination in the sanitation sector has been on building large-scale, sophisticated, and costly infrastructure in comparison to decentralized measures and alternate revenue mechanisms like user taxes. It is also essential to explore the notion of establishing "sustainable thinking in economic thinking" (Abeysuriya, Mitchell, and Willetts 2008) by enabling decentralized and distributed options regionally.

Currently, decentralized systems are widely implemented through public–private partnership mechanisms and nongovernmental occupations in sanitation-related projects in developing countries, predominantly in South Asia. Yet, these interventions are limited to a few motivated and passionate individuals or groups. Decentralization is usually considered to be more costly due to its misrepresentation of sunk costs and a lack of consideration of the avoided costs (Domenech 2011; Fane and Mitchell 2006). For the decentralized sanitation sector to grow, innovative and diverse financing mechanisms are required to help advance the pace toward safe sanitation access and treatment. It is also essential to understand that not all regions and communities are dealing with the same set of problems and that every region and subregion will need tailor-made financial, institutional, and governance measures to tackle individual problems.

The potential of microfinance loans for decentralized sanitation systems in developing countries has often been considered. Governments and policy makers have refuted that microfinance loans for the water and sanitation sectors are too much of a financial risk and put pressure on households (Pories 2015). In fact, conventional models of financial institutions developing loan portfolios for designing and constructing household-level water and sanitation facilities are not yielding the desired results. This is supported by Pories' 2015 study, which calculated the time spent by the members of a household to collect water and travel for open defecation. Data collected through the study show that households that took loans to construct water and sanitation facilities gained newly freed-up time for income-generating activities, with women being the most economically active. Of the women studied, 17.4% were able to work additional hours, and 6.1% entered the workforce for the first time. Therefore, while governments argue that investment in sanitation is expensive, the rate of return is low. While increased tariffs can put greater pressure on households through microfinance loans, Pories supports the argument that even though the initial investment in sanitation-related infrastructure may be steep, it allows people to save time and enables greater income generation, thereby increasing consumers' ability to pay additional tariffs.

This indicates that, "innovative non-traditional financing mechanisms like micro-loans for consumptive purposes in the sanitation sector may not be as risky as assumed and in fact generating additional income for households" (Pories 2015). Through regulated policy frameworks, such innovations can cultivate decentralized systems that eventually benefit communities, facilitating not only economic development but the general well-being of populations.

The governance and institutional structures for sanitation projects are also concerning. Until recently, public organizations were the sole providers of the most basic consumer utilities, such as water, sanitation, and transport. In recent years, several non-state actors, especially in developing countries like India, Bangladesh, Nepal, and some African countries, have invested heavily for the betterment of the sector. However, scholars and analysts have yet to acknowledge the combination of state and non-state providers prevalent in the sector and identify their role through a regulatory mechanism (Post, Bronsoler, and Salman 2017). The involvement of non-state actors is already prevalent where decentralized approaches are being implemented. It is, therefore, significant that developing countries are already using hybrid unregulated systems for service delivery. However, service provision in the water and sanitation sectors has largely been a public engagement and has been heavily associated with the politics of user charges and the effects on the fate of regimes, where the overall sentiment has been protective. With the advent of NGOs, private company providers for FSM, and social enterprises working in the sector, service provision has been highly fragmented and unregulated, resulting in a lack of organized replicability and scalability. This situation has helped to resolve issues in some regions sector-wise but has not addressed the larger sanitation issue. Therefore, it is imperative that government and sector specialists look at regulatory mechanisms to amalgamate this hybrid model of state and non-state actors to effectively work together.

2.3.5 Political Will as the Key Driver in Prioritizing Sanitation and the Role of Data in Evidence-based Decision Making

In light of the initial observations presented in this chapter concerning country comparisons of sanitation coverage and GDP, the trajectories of Malaysia and the Republic of Korea are highly remarkable. In the case of the Republic of Korea, the water and sanitation sectors were continuously linked to industrial and economic growth, thereby creating long-term momentum for them to grow through robust institutional mechanisms (Korea Water and WasteWater Works Association n.d.). Creating an enabling platform for sanitation has highlighted the prescient understanding and analysis of governments that had the ability and the inclination to prioritize sanitation as a means to larger economic regeneration.

The global political understanding of sanitation has been that sanitation is a by-product of economic growth, with a micro-level reliance on the concept that greater household income leads to better sanitation (Water Aid n.d.). In both the Republic of Korea and Malaysia, studies have indicated the opposite: that sanitation was prioritized from the beginning so that cities, towns, and regions could become self-sustained corridors. For both countries, sanitation was included in the early development plans, with leaders and institutions playing a central role in the development of the sector. Leaders in Malaysia, from 1955 onward, included and linked sanitation with economic development. Rural sanitation was of key importance, with an emphasis on donor and development aid to focus on money-earning, health, happiness, and social-development projects (Water Aid n.d.). This was accomplished by making rural development central to the policy framework and limiting rural-to-urban migration by creating self-sustained and comfortable living environments in rural areas.

One of the primary tasks was the provision of basic services such as water supply, sanitation, electricity, and transport. The prime minister and the chief ministers in Malaysia reiterated the importance of safe sanitation and made it central to all the decision making for development. The larger consensus within the sanitation sector has relied on the idea that it is the result of development efforts, rather than the key mechanism for it. This is supported by the beliefs that countries need to reach a certain GDP landmark to be able to attain complete sanitation coverage and that community-based initiatives and behavior change are key to the sanitation revolution (Water Aid n.d.). Table 2.1 challenges these beliefs. It is evident that when the countries reached a nominal 40% sanitation coverage, the GDP subsequently inflected over a medium- to long-term period. Table 2.1 also demonstrates how Japan, the Republic of Korea, and Thailand emphasized sanitation long before economic development.

The Water Aid report on Malaysia's rural sanitation program describes how it was integrated into its poverty eradication programs. The Rural Environmental Sanitation Program was designed to improve the well-being of those in impoverished areas and the Rural Development Program resettled people into more productive lands equipped with improved sanitation facilities. These reforms tackled sanitation early on, with institutions and organizations improving over time. Improvement was possible because senior leadership prioritized sanitation in their broader agenda of national and rural development. The Malaysian case strongly supports the argument that facilitating access to sanitation in rural areas was not something completely left to individuals and communities but was actively pursued by the government through donor and development aid.

It is essential to understand that countries whose governments prioritized sanitation by strategic planning, supported by strong leadership and political will, created a chain of institutional and governance structures that effectively mitigated the sanitation challenge early on with low financial investments coupled with a lack of returns on primary expenditures—however, they eventually received high returns over time. In the present scenario, it is essential that community-oriented and multi-stakeholder approaches be combined with a consistent political will and related governance mechanisms.

As a final point, it is essential to grasp that to tailor any action toward innovative solutions and to leverage the sanitation sector, informed understanding of the basic realities is required. There is a need for an evidence-based approach to make appropriate sanitation improvements. One of the pressing needs in the sector has been the lack of regular and accurate data collection efforts. The development of the WASH sector has been viewed as either involving appropriate infrastructure provision or encompassing financial allocation, budgeting, and resource management. We observe that to make further improvements in sanitation, resource allocation, and associated decision-making, it is important that a data-driven approach is undertaken.

2.4 Conclusion

Throughout history, the importance of wastewater management has not been accurately understood, particularly regarding its economic benefits. Life in many countries has carried on without sanitation, despite knowledge of the benefits that come from decentralized systems for small populations instead of large treatment plants. Sanitation tariffs have consistently focused on full-cost recovery and, thus, on large-scale technological solutions, while not entirely considering the potential from tax revenues stemming from the "user pays" principle. This chapter has combined and analyzed the available literature and presented a new way to think about the sanitation challenge. Using decentralized and distributed options, tailor-made solutions must be devised according to local contexts using innovative financing mechanisms. The standardization of available technologies with adequate community participation is critical for resolving issues on a region-by-region basis. With growing demands from urbanization and migration, it is imperative that a hybrid governance model be adopted, including state and non-state actors, to collectively contribute toward the implementation of sanitation projects at various scales. Consequently, it is significant to understand that access to improved sanitation and wastewater management has benefits that greatly counter the negative effects of a lack thereof on gender, education, and economic growth. The spillover effects from sanitation lie beyond the periphery of its immediate impacts and, concurrently, result in greater economic prosperity and social well-being over a long period of time, leading to a sustainable environment. Ultimately, this chapter emphasizes that countries need to immediately prioritize and invest in sanitation through dedicated political will, evidence-based decision-making, and government support. When relevant stakeholders understand the far-reaching spillovers of decentralized and community-driven projects, we hope they will replicate and scale up such projects.

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3

Encouraging Private Financing for the Supply of Water through Spillover Tax Revenues

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3.1 Spillover Effects Created by Infrastructure Investment

This chapter will discuss how to bring private-sector financing into the water supply.

Infrastructure investment is important in many developing countries for highways, railways, electricity supply, water supply, and sewage, among others. Although public–private partnerships have long been discussed, many countries have faced difficulties in engaging private-sector money.

When highways, railways, and water supply infrastructure are built, the value of the appropriated land increases. New apartments can be constructed, and new businesses will start in their proximity. Restaurants can be started in the region. In the case of Japanese railways, using public–private partnerships, they used land capture caused by new infrastructure investment to develop the farmland through which they built railroads into residential areas, and then built department stores near the stations. These transport-oriented development activities were of great benefit to private railways so that they could be certain about revenue. Since user charges, such as train fees and water tariffs, are usually very low, railways and water supply and other infrastructure companies that rely on them struggle with revenues. Water supply and electricity, especially, are necessary goods, and the government cannot increase user charges. For ordinary roads, users cannot be charged, so user charges are nonexistent. It is impossible to invite private investors into the development of such infrastructure because the rate of return they can expect is too low to cover construction, operation, and maintenance.

In macro estimation, Yoshino and Nakahigashi (2004) used a trans-log production function in Japan to estimate the direct effect of infrastructure investment and the indirect effect of spillovers. The direct effect of investment is created by the infrastructure that will increase the output of the region. Spillover effects will have two channels. One is the construction of new office buildings and new housing resulting from improved water supply and electricity, which will in turn optimize land use. The second channel is increased employment as improved water supply, railways, and roads attract businesses, restaurants, and new residents into the region. New apartments and new factories will be constructed, which will increase regional output, thus contributing to increased consumption and housing. The gross domestic product (GDP) in the region will further increase.

Whether or not the investment is effective is verified by estimating the effect of infrastructure using a production function.

$$Y = f(K_P, L, K_G) \tag{1}$$

Here, we use what can be described as a trans log production function.

$$\begin{aligned} \ln Y = \alpha_0 + \alpha_1 \ln K_P + \alpha_2 \ln E + \alpha_3 \ln K_G + \beta_1 \frac{1}{2}(\ln K_P)^2 \\ + \beta_2 \ln K_P \ln L + \beta_3 \ln K_P \ln K_G + \beta_4 \frac{1}{2}(\ln L)^2 \\ + \beta_5 \ln L \ln K_G + \beta_6 \frac{1}{2}(\ln K_G)^2 \end{aligned} \tag{2}$$

To examine the productivity effect of infrastructure in greater detail, its direct and spillover effects were classified according to Yoshino and Nakano (1994). Direct effects refer to increments in production by a marginal increase in the production factor (private capital and private labor) due to an increase in infrastructure. Spillover effects refer to production increases by private enterprises additionally investing in production elements based on their initial increase in marginal productivity. In cases employing the production function of equation (2) and for which factor prices and infrastructure are given to private sector producers, the productivity effect of infrastructure is classified into three categories. In equation (3), the first term on the right comes under the direct effect, the second term is the spillover effect with regard to the private capital, and the third term represents the spillover effect related to the labor input. The effect of infrastructure is expressed in marginal productivity.

$$\frac{dY}{dK_G} = \frac{\partial f(K_P, L, K_G)}{\partial K_G} + \frac{\partial f(K_P, L, K_G)}{\partial K_P}\frac{\partial K_P}{\partial K_G} + \frac{\partial f(K_P, L, K_G)}{\partial L}\frac{\partial L}{\partial K_G} \quad (3)$$

Table 3.1 estimates the direct effect of infrastructure investment and its spillover effects using macro data of Japan. The detailed method of estimation can be found in Nakahigashi and Yoshino (2016). In 1966–1970, the direct effect of infrastructure investment that increased output was 0.638 (the first row of Table 3.1). The spillover effect induced by an increase of private capital was 0.493 (the second row of Table 3.1), and the spillover effect induced by increasing employment was 0.814 (the third row of Table 3.1). The biggest spillover effect was increasing employment, which contributed to an increase in output.

Table 3.1: Economic Effect of Infrastructure Investment in the Case of Japan

Economic Effect	1956–1960	1961–1965	1966–1970	1971–1975	1976–1980	1981–1985
Direct effect	0.696	0.737	0.638	0.508	0.359	0.275
Indirect effect (private capital)	0.452	0.557	0.493	0.389	0.270	0.203
Indirect effect (employment)	1.071	0.973	0.814	0.639	0.448	0.350
100% returned case (%)	2.189	2.075	2.050	2.022	2.002	2.010
50% returned	0.762	0.765	0.653	0.514	0.359	0.276
% increment	1.095	1.038	1.025	1.011	1.001	1.005

Economic Effect	1986–1990	1991–1995	1996–2000	2001–2005	2006–2010
Direct effect	0.215	0.181	0.135	0.114	0.108
Indirect effect (private capital)	0.174	0.146	0.110	0.091	0.085
Indirect effect (employment)	0.247	0.208	0.154	0.132	0.125
100% returned case (%)	1.961	1.959	1.949	1.952	1.953
50% returned	0.210	0.177	0.132	0.111	0.105
% increment	0.980	0.979	0.975	0.976	0.977

Source: Yoshino, Nakahigashi, and Pontines (2017).

3.2 Infrastructure Needs in Asia and the Pacific

Table 3.2 shows the infrastructure investment needs in various Asian regions, as estimated by the Asian Development Bank (ADB 2017). Table 3.3 shows the kinds of infrastructure needed in Asia and the Pacific region. In the last column, electricity generation shows the highest need for investment, representing about 51.8% of the total, followed by transport, telecommunications, and water and sanitation. In order to satisfy such a big demand for infrastructure, private financing is necessary together with public finance.

Table 3.2: Infrastructure Investment Needs by Region, 2016–2030
(annual average, $ billion in 2015 prices)

Region	Baseline Total	Share of GDP (%)	Climate-Adjusted	Share of GDP (%)
Central Asia	33	6.8	38	7.8
East Asia	919	4.5	1,071	5.2
South Asia	365	7.6	423	8.8
Southeast Asia	184	5.0	210	5.7
Pacific	2.8	8.2	3.1	9.1
Asia and the Pacific	1,503	5.1	1,744	5.9

Source: Asian Development Bank (2017).

Table 3.3: Infrastructure Investment Needed in Asia and the Pacific by Type, 2016–2030
($ billion in 2015 prices)

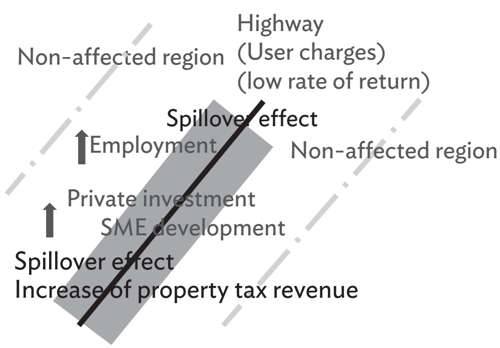
	Baseline Estimates		
Sector	Investment Needs	Annual Average	Share of total (%)
Power	11,689	779	51.8
Transport	7,796	520	34.6
Telecommunications	2,279	152	10.1
Water and sanitation	787	52	3.5
Total	**22,551**	**1,503**	**100.0**

Source: Asian Development Bank (2017).

3.3 Diagrammatic Explanation of Spillover Effects Created by Water Supply

Figure 3.1 demonstrates the spillover effects, also known as the externality effect, of the water supply. Suppose that the middle black line is water supply and new water supply to be constructed. Then, in the region along these water supply corridors, new industries and new companies start their manufacturing activities. Housing can be constructed along new water supplies. Restaurants and the services sector also start their businesses. So, the dark gray part of Figure 3.1 enjoys spillover effects created by the new water supply. This economic development will increase regional tax revenues for local government; property tax revenue as well as business, income, and sales taxes will all increase. However, all these incremental tax revenues in the past went to the local and central government and were not returned to infrastructure investors, who relied only on user charges for their sources of return.

Figure 3.1: Spillover Effect of Water Supply



SME = small and medium-sized enterprise.

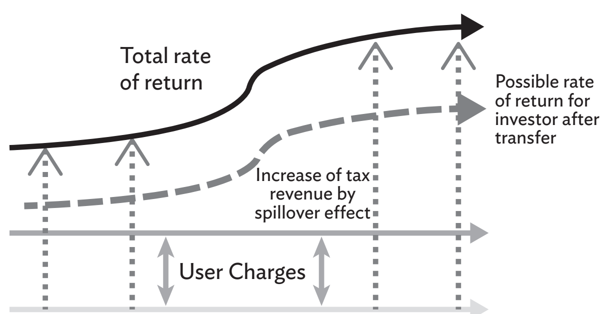
Source: Authors.

3.4 Increases in Tax Revenues by New Infrastructure Investment

Yoshino and Abidhadjaev (2017a) have estimated the microeconomic impact of spillover effects for railways in Uzbekistan, while Yoshino and Pontines (2015) have estimated the impact of highways in Manila, and Yoshino and Abidhadjaev (2017b) have estimated the impact of the Kyushu rapid train in Japan. All these studies have estimated the spillover effects of infrastructure investment and found that their increase raised tax revenues.

Figure 3.2 shows user charges and increased tax revenues created by infrastructure investment. The gray line at the bottom represents user charges. Traditionally, private investors for infrastructure relied only on user charges, such as railway tariffs, highway tolls, water tariffs, etc. Water and electrical supply are public and necessary goods, and user charges for this infrastructure are regulated to keep them as low as possible (Figure 3.2). However, water supply can create big spillover effects in the region. An increase in regional GDP will increase tax revenues, as shown by the black line. Assuming that 50% or 60% of these increased tax revenues is returned to the infrastructure investors, the gray dotted line becomes the investors' total revenue. The rate of return rises to the gray dotted line from the user charges (green line). If these spillover tax revenues, which were co-created by the new water supply, were partly returned to the infrastructure investors, then the actual rate of return on investment rises significantly. This can induce private investors to participate in water supply infrastructure.

Figure 3.2: User Charges and Spillover Tax Revenues



Source: Authors.

Manila is the only example where an urban water supply company is also enjoying revenues from residential development. There, the company captures the increase of property values by purchasing the land before the water supply is completed. This land capture increases the revenue for the water supply company. The land capture is only a one-shot gain for the company; if the spillover tax revenues were returned from the government to the infrastructure investors, the rate of return would keep rising for the entire period.

Table 3.4 shows the case of the Southern Tagalog Arterial Road (STAR) Highway in Manila (Yoshino and Pontines 2015). The periods t-1 and t indicate periods under construction. At the end of t, the highway had been completed and started operation. In the last row, Batangas City, t-2 was the period when construction was not going on, and t-1 and t were periods when construction had started. As indicated, tax revenues increased from 490 to 622 and 652 (last row). During the highway construction, workers and related works came to the region, which increased regional GDP. At the end of t, the STAR Highway had been completed. Then at t+2, the tax revenue diminished compared to the construction period. But after the fourth year, the tax revenue increased drastically. At t+4, the tax revenue went up to 1,208, about twice as much as before the construction. These are the spillover tax increases coming from infrastructure investment, in this case the STAR Highway. These are the increased tax revenues, not the existing ones. If the highway were not constructed, the tax revenues would have been 490 (t-2). Because of the highway construction and increased economic activities, Batangas City gained tax revenues of 1,208. If the part of these incremental tax revenues (that is, 1,208–490) were returned to private investors, they would be willing to invest their money for constructing the highway. The same effects can be applied to construction of new water supply infrastructure.

Table 3.4: Changes in Tax Revenues in Three Cities along the STAR Highway in Manila
(₱ million)

	Period						
Location	t-2	t-2	t0	t+1	t+2	t+3	t+4, forward
Lipa City	134.36	173.50	249.70	184.47	191.81	257.35	371.93
Ibaan City	5.84	7.04	7.97	6.80	5.46	10.05	12.94
Batangas City	490.90	622.65	652.83	637.89	599.49	742.28	1,208.61

STAR = Southern Tagalog Arterial Road.
Source: Yoshino and Pontines (2015).

3.5 Financing for Water Supply

In Figure 3.3, there are five different methods of private finance: (i) bank loans, (ii) insurance funds, (iii) pension funds, (iv) revenue bonds, and (v) equity investment. Bank loans are usually relatively short, from

Figure 3.3: Different Classes of Infrastructure Assets and Different Kinds of Finance

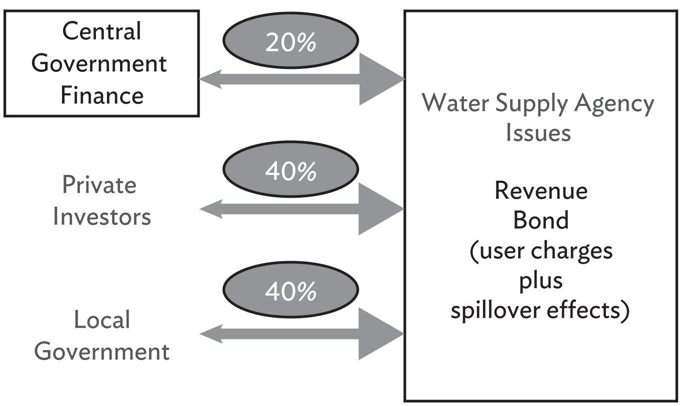
Source: Authors.

1 to 5 years. The length of time for insurance is about 10–20 years, and pension funds will be much longer. Many Asian countries will be faced with aging populations. Public pension funds must be well established, and private insurance systems must be established to cope with this future aging population. Once collection begins for pension and insurance funds, there must be a place to invest these long-term assets. Infrastructure investment needs are huge in the Asian region, and water supply is especially difficult to induce private-sector financing. Spillover tax revenues must be returned to investors in this case, or water shortages will continue. If the rate of return were increased, private investors would be willing to invest in construction and other up-front costs.

The right-hand side of Figure 3.3 shows safer infrastructure assets at the top and riskier ones at the bottom. There are many different kinds of asset classes in infrastructure investment. Safe assets may be represented by brownfield land. The private sector can see continuous revenues from infrastructure such as railways or highways that have already been in operation. If the rate of return from existing infrastructure is high, private investors can invest in brownfield infrastructure. Risky infrastructure assets are those, such as new projects, whose potential revenues are unknown. If infrastructure spillover tax revenues were returned to investors, as proposed, the rate of return for private investors would be increased significantly. Even risky infrastructure assets can be turned into safer assets. Thus, we can increase the rate of return for all the kinds of infrastructure investment, and we can increase safer assets that will allow pension and insurance funds to invest domestically.

The next type of financing is revenue bonds for water supply. The water supply agency, which can capture not only user charges but also part of the spillover tax revenues, can earn sufficient revenue every year (Figure 3.4). The agency can issue revenue bonds, for which the interest rate changes based on the user charges and spillover taxes. If the business goes well, the spillover tax revenues will keep on rising, and the interest rate on the bond will achieve a higher rate of return. Revenue bonds can be purchased by a mix of entities; such a mix, for example, might include the central government (20%), private investors (40%), and the local government (40%). The entities are then sharing all the risks together, and they are also sharing the benefits, each in proportion to their investment.

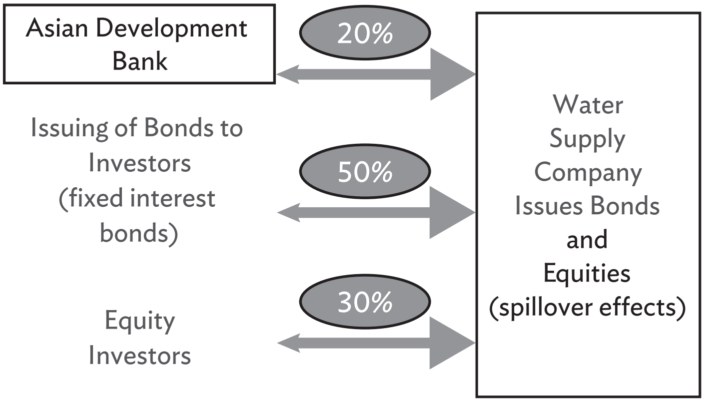
Figure 3.4: Revenue Bonds for Water Supply



Source: Authors.

Figure 3.5 illustrates equity and bond investments in infrastructure. The right-hand side shows that the water supply company issues bonds and raises money from the equity market. User charges and spillover effects are both returned to bond holders and equity holders. Such a mix, for example, might include 20% from ADB, 50% from fixed interest rate bonds, and 30% from the stock market. If spillover tax revenues were returned to infrastructure investment investors, then the rate of return of this fixed bond would become significantly higher. The last portion is equity investors. If the rate of return from user charges and spillover tax revenues rose much higher than expected, then the equity investors in the bottom 30% would enjoy significant benefits.

Figure 3.5: Equity and Bond Investment for Water Supply



Source: Authors.

3.5.1 Various Risks Associated with Infrastructure Investments

There are various ways to finance water supply. However, there are also various risks associated with infrastructure investment. There is political, construction, and operation and maintenance risk; if the investors are coming from overseas, then they also must face exchange rate risk. Recently, environmental hazards have also posed additional risk. As a result, total costs of construction have continued to increase, even exceeding the revenue from user charges.

3.6 Models for Returning Fractional Spillover Tax Revenues to Investors in Water Projects

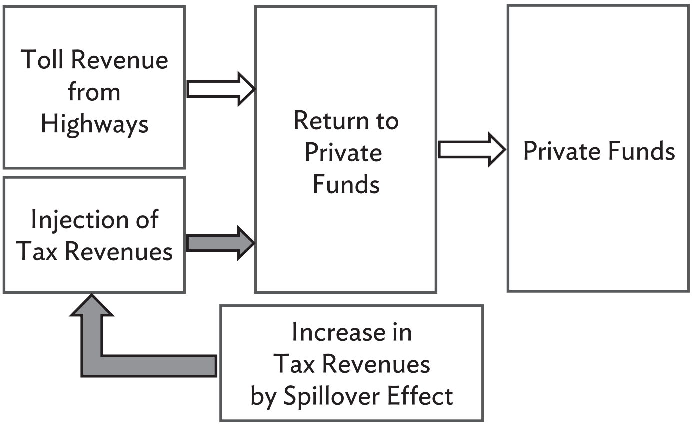
User charges are much less than the total cost of constructing and maintaining water supplies. Therefore, we are proposing to use spillover tax revenues created by the water supply. Property tax revenues have been used in the United States to add the rate of return to infrastructure investors. But the current proposal is not only for property tax revenues; in addition, corporate business taxes, income taxes, and sales taxes should all be returned to the infrastructure investors. These increased spillover tax revenues should be shared with the government and private investors in infrastructure investment.

By recommending that infrastructure firms develop nearby territories, we would like to point out that such an approach would not lead to the creation of monopolies in terms of services. Issuance of infrastructure bonds and their wide dissemination in the market will increase the number of owners. At the same time, once the infrastructure firm diversifies, with its revenue streams stemming not only from water tariffs and fares but also from spillover tax revenues, then the utility companies can lower water tariffs and fares, which will make households better off. This will affect the local economy and raise the marginal productivity of the capital, resulting in increased tax revenue holding the tax rates constant. When part of this net increase in tax revenue is returned to the infrastructure firm, utility fees will be pushed further downward, increasing the chances of survivability of the project and sustainable development of the region.

Additionally, it is very important to ensure that contracts are clear and transparent. In some developing countries, contracts may lack clarity, resulting in higher costs of construction. If international organizations such as ADB and the World Bank jointly participate in water supply projects, they can monitor the clarity and transparency of the contract, minimizing construction and maintenance costs. Otherwise, infrastructure costs will accrue, and it will affect the clarity and transparency of infrastructure projects. Another point relates to overseas loans. In cases where, for example, ADB, the World Bank, or a country provides loans to another country to construct a water supply, taxpayers' money is traditionally used to repay that loan. However, the proposed method of utilizing spillover tax revenues will allow the borrowing country to easily repay that loan because incremental tax revenues for the country and the region mean that infrastructure investors and construction companies, for example, can receive 50% of tax revenues in addition to user charges. That means lenders or construction firms involved in the water supply project can receive enough rate of return for this project, as long as water supply has enough spillover effects.

Figure 3.6 shows a model for the return of spillover tax revenues to private investors. At bottom are increased tax revenues created by spillover effects of the water supply. Then, the spillover effects will be injected as subsidies by the government to private investors. In this case, if the local government receives total spillover tax revenues, it will inject a proportion to private investors.

Figure 3.6: Injection of a Fraction of Tax Revenues as a Subsidy



Source: Authors.

3.7 Increasing the Spillover Effects from Water Supply

Finally, there is the matter of the financing of start-up businesses together with water supply. If clean water is supplied in a new region, many entrepreneurs will be interested in starting their own restaurant or other business, because new residents will be available as customers. However, start-up businesses often find it difficult to raise money, and banks often deny loans to them. The idea of hometown investment trust funds began in Japan about 20 years ago and then expanded to Cambodia, Viet Nam, and Peru. In these types of hometown crowdfunding, money is collected from individuals in the region. When water supplies begin, people in the region contribute money—perhaps $50–$100 by 200–300 people, to local business entrepreneurs. Hometown crowdfunding can lend money to start-up businesses. The water supply is very important to regional development. At the same time, financing for small businesses along with the new water supply will mitigate income inequality and create business opportunities to start-ups. Spillover effects from the water supply will be increased by allowing new start-ups in the region.

Hometown crowdfunding can finance not only the water supply, but also provide funding to develop new businesses within the water supply region, which will create bigger spillover effects. In this case, many more investors will be willing to invest.

3.8 Proper Tax Collection and the Prevention of Tax Evasion

Tax collection in many developing countries is difficult. Small and medium-sized enterprises do not pay tax, and even large businesses hide their revenues. Finance Minister Dominguez of the Philippines and Yoshino came up with a new idea of using satellite data for proper tax collection. How many people are coming to shopping malls every day? How many people are coming to restaurants? For how many hours is the restaurant open? How many tracks are coming to the factory? How much greenery does this farmland contain? Satellite data can provide tax authorities with rough figures of business activities and even estimates of farm crops. Such satellite data could capture spillover tax revenues properly, which would increase the rate of return to investors in water supply.

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PART II

International Case Studies

4

Quantifying the Economic Spillover Effect for Citywide Fecal Sludge Management Programs

David Robbins, KE Seetha Ram, and Nuobu Renzhi

4.1 Introduction

The economic spillover effect relates to ancillary benefits from development projects beyond their intrinsic values. For citywide fecal sludge management (FSM) projects, such benefits could be increased property values and tax revenues as the environmental health of the city improves over time. Other potential ancillary benefits include (i) increased tourism as the water quality of bays, beaches, and rivers improves; (ii) livelihood opportunities as pollution is reduced in fisheries; (iii) health improvements and increased worker productivity; and (iv) overall economic development.

To illustrate these spillover effects, this chapter looks at two projects in the Philippines: the Dumaguete City FSM program, on the island of Negros in central Philippines, and the Veterans Water Reclamation Facility (known as Project 7), a co-treatment program in Manila in the National Capital Region.

Both Dumaguete City and Project 7 are existing citywide FSM programs that have generated enough data to support a model for spillover effect valuation, which can be illustrated as follows:

Value of an FSM project = intrinsic value of the project +
additional internal effect values +
external spillover effect values

Additionally, we present a methodology to quantify the spillover effect values, represented mathematically as:

$$\textit{Spillover Value} = (G_a - G_0) \times I \times C \times L,$$

where the spillover value[1] of a benefit or parameter is equal to the product of

- the difference between the growth trend projected after the commissioning of the project (G_a) and the growth trend before the project (G_0);
- the impact factor (I), which is defined by the level of impact on the parameter by poor sanitation;
- the correlation factor (C), which is based on the likelihood that the intervention (the FSM project) will sufficiently address the impacts over time; and
- the linkage factor (L), which describes how FSM is related to other issues that are impacting upon the benefit or parameter.

Determining the expected spillover effect values for projects that have not been built yet is a subjective process. The methodology presented herein is designed to provide a platform where practitioners can evaluate the variables based on likely scenarios as their city develops over time. A toolkit (under construction) is introduced that simplifies the math through a questionnaire interview format.

4.2 Spillover Effect of Sanitation Improvement

Developing countries throughout Asia have made impressive gains in sanitation improvement through efforts to reduce open defecation and improve toilet coverage as measured by the Millennium Development Goals.[2] Toilets function by collecting the fecal waste and separating it from residential environments. To function effectively, toilets must either be connected to sewers that convey wastewater to off-site treatment works, or to on-site wastewater management systems consisting of septic tanks and pits that are designed to contain the fecal sludge, while dispersing the effluent through soil-based systems. Establishing sewer systems is expensive and generally beyond the capability of all but the largest cities. Therefore, on-site wastewater management is the

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1 Spillover value is presented as a percentage of growth of the parameter tested.

2 United Nations. Millennium Development Goals. http://www.un.org/millenniumgoals/environ.shtml (accessed 20 March 2018).

only other alternative. To function effectively, on-site systems must be properly sized and maintained, which requires periodic desludging.

As more people begin to rely upon on-site wastewater treatment systems (as open defecation decreases), hygienic citywide fecal sludge management programs become critical. Most cities in Asia have some form of septic tank or pit latrine desludging service. These may range from unhygienic services performed by informal desludging crews that operate on a demand basis, to government-organized programs that provide citywide desludging services on a rotating schedule. While the latter are rare, where they do exist, these organized programs accomplish the collection, transport, and treatment of the fecal sludge and septage, as well as the reuse or dispersal of the treatment by-products. The intrinsic value of these programs is in reducing the amount of fecal waste and pathogens discharged into the environment, while reducing the threat of infection from the pathogens found in wastewater.

There are often ancillary impacts associated with FSM programs beyond the intrinsic values that are realized as sanitation improves in a given community. These must be considered when looking at overall program costs and benefits. These economic impacts may include (i) increases in property values and the associated tax revenues, (ii) increases in tourism and its associated revenues, (iii) overall economic development that can be enabled as citywide sanitation improves, and (iv) environmental health improvements and other related benefits. These parameters may be considered "spillover" effects realized from the FSM program. In some instances, organized FSM programs can be integrated into existing or planned sewerage programs and realize "internal" program benefits. The most common example of this is the internal program benefits realized through co-treatment, or the co-management of fecal waste with the city's sewage. In these programs, costs are reduced through efficiency of operations, while value is added through increased utilization of the treatment plant or avoiding the cost of stand-alone fecal sludge treatment systems. The spillover effects of FSM programs may be substantial. In the two city examples provided, the spillover effects are greater in terms of economic value than the original capital costs of the programs. Quantifying the spillover effect can provide a significant motivator that can be used to persuade local decision makers to accelerate citywide FSM programs.

4.2.1 Sanitation Success Stories from the Philippines

The Philippines has witnessed impressive economic growth in recent years. From 2010 to 2017, the country has achieved an average gross domestic product (GDP) growth rate of 6.4%, which is a great achievement compared to the average GDP growth rate of 4.5% in 2000–2009 and 2.4% in 1980–1999. This rapid growth also has drawn the attention of many researchers and policy makers. Felipe and Estrada (2018) show that the recent economic growth in the Philippines is mostly driven by the increase in labor productivity growth in the manufacturing and service sectors. Yoshino and Nakahigashi (2018), by using Thailand data, give further evidence that the increase of labor productivity growth in the manufacturing and service sectors is largely caused by the positive effect of infrastructure investment. The *Asian Development Outlook 2018* also points out that infrastructure development in the Philippines fuels its strong economic performance.

Conversely, the Philippines also has large disparities in terms of regional economic growth. The Central Visayas region had an average GDP growth rate of 8.2% in 2010–2017 and contributed 7% of GDP growth in the whole country, making it the fifth largest contributor to the country's economy. However, the province of Negros Oriental in the Central Visayas region has been one of the poorest provinces in the country. Inadequate infrastructure has been a critical constraint to local economic growth (ADB 2007), as it increases the cost of business activities and has an adverse impact on local property values. Combating the poverty in the province requires more infrastructure investment to decrease business cost and create more economic opportunities. In 2010, the local government in Dumaguete City embarked on a program to do just that—by starting the full operation of the citywide FSM program.

4.3 Dumaguete City Fecal Sludge Management Program

4.3.1 Background

Dumaguete City is located in the province of Negros Oriental in central Philippines. Its population is approximately 130,000 people. Planning for their FSM program began in 2006 and was fully operational full operationalization in 2010. The program provides citywide FSM services for desludging most septic tanks on a 5-year rotating schedule. It includes a fecal sludge treatment plant as well as a fleet of seven desludging trucks. The program was implemented in parallel with other sanitation improvements including a properly functioning on-site wastewater system for the public market.

Dumaguete City represents a model for how local governments can actualize cost-recoverable and sustainable citywide FSM programs.

The basic concept behind the program is that if everyone pays a small amount, it could fund the capital as well as operational expenses of the service. In this instance, the small amount is a tariff of around $1 per family per month that is attached to the water bill and collected by the water district. This was enough to achieve full cost recovery for the capital and operational expenses in 6 years. The service is septic tank desludging for residential, commercial, and institutional on-site wastewater systems on a 5-year cycle. The monthly tariff is easier for families to afford than having to pay a lump sum.[3]

In Dumaguete City, septic tank desludging services are provided through a program that is jointly managed by the city government (or local government unit) and the Dumaguete City Water District. The water district maintains and operates the fleet of seven desludging vehicles, while the local government unit maintains and operates the septage treatment plant. The treatment plant uses waste stabilization pond technology and was designed with an operational capacity of 85 cubic meters of septage per day. Tariffs are collected to cover the cost of the services including full cost recovery for the capital expenditures (CAPEX) and operational costs (OPEX).

Prior to the investments, the bay fronting the downtown area was experiencing degraded environmental health due to unregulated discharge of sewerage and septage. Eight years after the sanitation improvements were commissioned, the nuisance is now reduced, and thousands of people use the waterfront park every day. Business revenue from restaurants and hotels fronting the bay have increased as have the property values and tax revenues. Rizal Boulevard fronting the bay is now an important tourism draw, resulting in more meals served at local restaurants and rooms rented at local hotels. There have been other economic spillover impacts as well that have been realized in Dumaguete City as a result of their FSM program. When the treatment plant was installed, as incentives to the host community, the local government improved the roads, built a health center, created a scholarship fund, and provided local employment opportunities at the fecal sludge treatment plant. Property values in the areas surrounding the treatment plant have since increased, and what was once a barren outskirt of the city is turning into an upscale residential neighborhood. These spillover effects, driven in part by the implementation of the FSM program, have resulted in real economic development that has had a significant and substantial impact on the city.

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[3] Interview with local government water district. For details, see video at https://www.adb.org/news/videos/spillover-effects-fecal-sludge-management-dumaguete-city.

4.3.2 Estimating the Value of Spillover Effects

To fully explore the spillover effect of the Dumaguete City FSM program, data were obtained from the city tax office, city health office, water district, and host community, with data points beginning in 2005, well before the implementation of the program. The trends were evaluated both prior to and after the commissioning of the FSM program.

4.3.3 Economic Data from the City Government

Key metrics in this category include (i) business taxes collected; (ii) number and type of business entities; (iii) business and residential rental costs; and (iv) activities related to tourism including number of tourists and of hotel rooms rented. The data show that, prior to the FSM program, the trends were low growth increasing at around the national rate of inflation. However, following the advent of the program, the growth trend in the metrics increased, with tax revenues and rental values somewhat above the national rate and with tourism-related activities well above the rates prior to the program.

Health Data from the City Health Office

The health data obtained from the municipal health office provide information on two metrics: (i) number of gastrointestinal disease incidents and (ii) number of waterborne disease outbreaks. It is assumed that improving citywide sanitation through septage management will have a positive impact upon health as the pathogen loading into the environment is reduced. Evaluating these impacts, however, is difficult. Disease reporting is not an exact science as many people, especially poor people, may not seek or may delay formal medical treatment for diarrheal diseases. Further, waterborne disease outbreaks are relatively rare in Dumaguete, so establishing trends is difficult. There may also be confounding factors, as all waterborne disease outbreaks or gastrointestinal disease events may not be due to contaminated septage or wastewater.

Data from the Water District

The data from the water district are used to find the intrinsic value of the FSM service by comparing the number of service connections and volumes of water delivered with the number of desludging events. They are also used to gauge the efficiency of the program by looking at percentages of customers that have their on-site systems desludged each year, and the overall percentage of residential and commercial buildings desludged within the 5-year cycle.

Data from the Host Community

The data from the host community look at the number of new homes and businesses, and associated property values, to gauge the economic benefits from the project. Other impacts are also captured, including (i) number of scholarships awarded that are funded through the FSM tariff, (ii) value of the health-care facility and of the services provided, (iii) value of the road improvements, and (iv) value of local employment realized through the project.

4.4 The Fecal Sludge Management Valuation Model

The economic model of an FSM program valuation shows that the total project value is equal to the sum of (i) the intrinsic value of the project, (ii) any internal benefits, and (iii) any spillover effect benefits.

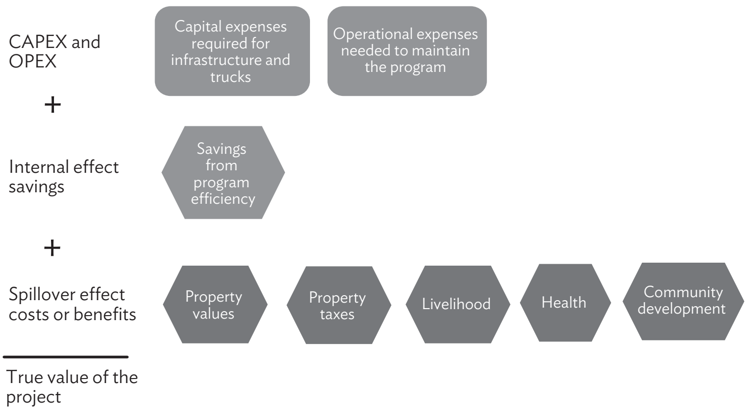
4.4.1 Methodology of Calculating Spillover Effect Values

From the model (Figure 4.1), we see that the true value of a project is equal to the sum of

- the intrinsic value of the project, represented by the initial capital expenses and the ongoing operational expenses;
- the internal savings through program efficiency; and
- the value of the spillover effect benefits including property values and taxes, livelihood opportunities, health improvements, and overall economic development activities.

The intrinsic value, represented by the CAPEX and OPEX, is a direct value that is easily obtained. The internal savings through co-treatment efficiency or other economies of scale can be modeled to obtain a fairly accurate valuation. This is presented for Project 7 in the next section. It is the spillover values that are normally not easy to measure. There are many potential external benefits (parameters) associated with citywide sanitation improvement that a community may realize.

Figure 4.1: True Value of a Sanitation Project



CAPEX = capital expenditures, OPEX = operational costs.

Source: Authors.

For Dumaguete City, they can generally be broken down into four categories. They are presented below along with their indicators:

1. Property values and real property taxes
   - Number of lessors
   - Number of building permits
   - Tax assessment totals
2. Tourism and associated revenues
   - Number of food service establishments
   - Number of hotels
   - Tourism tax revenues
3. Economic development
   - Number of banks and financial institutes
   - GDP for the city
4. Health
   - Number of reportable diseases
   - Worker productivity

Variables to consider when estimating the spillover effect are the following:

- impact (*I*): the degree that the parameter is impacted by poor sanitation;
- correlation (*C*): the likelihood that the intervention will improve the condition;

- growth trend (percentage) prior to the implementation of the FSM project (G_0);
- growth trend (percentage) anticipated after the project (G_a); and
- linkage (L): the link between the intervention and the growth of the parameter.

This can be shown mathematically through the following formula:

4.4.2 The Impact (I) Variable

Determining the impact of a proposed intervention (implementing an FSM program) is subjective, often relying upon opinions where solid data are not available. Using this methodology along with sound planning and visioning exercises can improve the accuracy of the valuations sought.

Property values and property taxes provide a good example for the discussion of the impact (I) variable. For Dumaguete City, there was a moderate association between the degraded environmental health of the bay and property values of the commercial and residential parcels fronting it. Consider Table 4.1, which presents a ranking of the possible impacts of poor sanitation on the property values parameter on a scale from 0 to 1, where 0 is no impact and 1 is a strong impact.

Table 4.1: Impact Variable and Ranking Criteria

Rank	Value
0 – There is generally no impact on properties from poor sanitation.	0.1
1 – There is a minor impact on properties due to poor sanitation.	0.2
2 – There is a distinct impact on properties due to poor sanitation.	0.4
3 – There is a definite impact on properties due to poor sanitation.	0.6
4 – There is a major impact on properties due to poor sanitation.	0.8
5 – There is an extreme impact on properties due to poor sanitation.	1.0

Source: Authors.

Using this ranking method, an investigator can break down the parameter (in this case, property values) into sub-parameters (Table 4.2). Consider these subparameters that are directly related to property impact by fecal sludge, and the associated ranking for Dumaguete prior to the FSM program.

Table 4.2: Subparameters for the Property Valuation Impact

Parameter	Impact Ranking
Properties are impacted by overflowing septic tanks or raw sewage.	0.80
Properties are impacted by odors from sewage.	0.80
Properties are impacted by vectors (flies, mosquitoes, helminths).	0.60
Overall impact (average of the three)	0.73

Note: Each issue is assumed to be of similar importance.
Source: Authors.

To calculate the impact value for property and tax values, first determine which subparameters are most relevant and then assess an impact ranking for each. Calculate the average impact ranking in order to obtain an estimate for the impact value for the overall parameter using the following formula:

$$\text{Impact value} = (.8 + .8 + .6) / 3 = .73$$

In Dumaguete, there were significant indications that improving sanitation would improve the parameter of property values. This is shown by a relatively high impact value of .73.

4.4.3 The Correlation (C) Variable

The correlation (*C*) variable describes the likelihood that the project will succeed and that the anticipated impacts will be realized for the development parameter being valued. In Asia, development projects sometimes do not fully succeed, and anticipated expectations may not be realized. This can be the result of (i) poor design or construction of physical facilities, (ii) lack of funding for long-term operation and maintenance, (iii) skill level of the operators, (iv) immature value chain limiting the flow of spare parts, (v) political or climate risks, and/or (vi) level of regulatory enforcement. FSM programs may not succeed in delivering anticipated environmental health improvements due to external factors as well. For example, property values may not improve after FSM programs are implemented if other factors such as solid waste or drainage are also impacting the property values.

For the correlation (*C*) variable, the same ranking system is used Table 4.3.

In Dumaguete, the indiscriminate dumping of septage prior to the intervention was believed to be impacting property values and therefore tax revenues. However, the city was new at septage management, and the

Table 4.3: Correlation Variable Ranking and Valuation

Rank	Value
0 – The project will likely not deliver the anticipated results for the parameter.	0.1
1 – The project will have minor success at delivering results for the parameter.	0.2
2 – The project will have limited success at delivering results for the parameter.	0.4
3 – The project will be moderately successful at delivering results for the parameter.	0.6
4 – The project will be significantly successful at delivering results for the parameter.	0.8
5 – The project is anticipated to fully succeed at delivering results for the parameter.	1.0

Source: Authors.

ability of the city to enforce the local ordinance on septage management was unknown. At the time of the intervention, a correlation rank of between 2 and 3 (correlation values of between .4 and .6) would have been a reasonable assumption, meaning a limited to moderate chance of achieving success at positively impacting property values through FSM. As it turned out, the correlation was more positive than initially thought. Looking back, it is easy to quantify the results of the septage management program and see the benefits. One can safely say that the project was moderately to significantly successful at delivering results for this parameter (improved property values), earning it an actual rank of 3 or 4. For this example, a rank of 3 is chosen, which equates to a correlation value of .6.

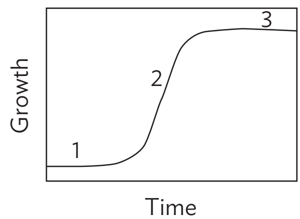
4.4.4 Growth Trend prior to Implementation (G_0)

Understanding the growth trends for certain parameters requires data. Dumaguete City has documented numerous data points that are useful for evaluating growth trends. For example, the number of banks and financial institutions is tracked each year. It is believed that the rate of growth in the number of banks and financial institutions is a good indicator of economic development.

To determine a growth trend prior to the project, one method could be to look at the first 2 years after the intervention when impacts are just starting to be seen. Interventions such as citywide FSM programs take time to scale up. It is reasonable to assume that spillover effect values would be minimal during the first 2 years of operation. Evidence from the Dumaguete City experience indicates that the spillover effect exhibits a logistic growth curve (Figure 4.2).

Figure 4.2: Phases of Logistic Growth Curve

1. Lag Phase – little initial growth
2. Rapid Growth Phase – exponential growth
3. Stable Phase – stabilizing factors limit growth



Note: Data from Dumaguete City indicate that spillover effect values exhibit similar phases with the lag phase sometimes extending 2 or more years until the project scales up.

Source: Authors.

Between 2010 and 2012, the number of banks and financial institutions increased at a rate of 1.04% per year, closely paralleling the population growth rate. This appears to be a reasonable correlation as the number of banks would be generally proportional to the population served. Any reported increase in the ratio of the number of banks to population would be due to some other factor, such as increased economic activity driven by tourism, for example.

For the purposes of quantification, the G_0 variable (the trend prior to the intervention) for banks and financial institutions in Dumaguete is 1.04.

4.4.5 Growth Trend after Implementation (G_a)

Fortunately, Dumaguete City has data on the number of businesses after the project intervention. These make it easy to calculate the growth trend after implementation. In this case, between 2010 and 2017, the average annual growth in the number of banks and financial institutions is 8%. Therefore, the G_a variable (the trend after the intervention) equals 8% growth per year (Table 4.4).

Table 4.4: Number of Businesses in Dumaguete City by Type, 2010–2017

Type of Business	2010	2011	2012	2013	2014	2015	2016	2017	% Annual Increase
Population	120,883					131,377			
Banks and other financial institutions	239	248	244	322	339	361	372	396	8
Caterers and food establishments	570	632	605	685	640	667	684	740	4
Manufacturing	150	150	138	152	153	165	157	166	1
Printing and publications	13	17	16	15	14	14	14	18	5
Real estate lessors	390	427	450	531	555	603	649	697	10
Retailers	1,676	2,632	2,500	2,748	2,730	2,858	2,887	3,102	10
Services	1,113	1,128	1,154	1,282	1,290	1,383	1,426	1,519	5
Wholesale/ distribution	164	179	170	197	207	201	201	190	2
Exempted business entities	49	195	87	196	171	79	114	134	22
Other impositions/ fixed taxes	No data	No data	2,344	2,516	2,430	2,490	2,470	2,578	
Total	**4,364**	**5,608**	**7,708**	**8,645**	**8,530**	**8,821**	**8,974**	**9,450**	**15**

Source: Dumaguete City.

The difference between G_a and G_0 therefore is the growth in economic development in the years following the intervention as expressed in the formula:

$G_a - G_0$ = additional growth for that parameter above the existing trend.

In this case, $G_a - G_0 = 8\% - 1\% = 7\%$ growth per year.

4.4.6 The Linkage (L) Variable

Economic dynamics in a city are complex, and growth in economic development for example may have a number of causes. The linkage (L) variable is used to reflect the degree that the project intervention is the causative factor in the rate of growth. In Dumaguete City, diverting the sewage from the public market to the treatment system instead of the bay, as well as collecting the septage and banning the indiscriminate discharge of septage, had a direct impact on improving the environmental health conditions in the central business district and around the bay frontage. Was that the only reason that tourism numbers began to increase around that time? Table 4.5 provides the rationale for this variable.

Table 4.5: Linkage Variable Ranking and Valuation

Rank	Value
0 – The intervention is not generally linked to growth of the parameter.	0.1
1 – The intervention is a minor factor in growth.	0.2
2 – The intervention is a significant factor responsible for growth.	0.4
3 – The intervention is a major factor responsible for growth.	0.6
4 – The intervention is the only factor responsible for growth.	0.8

Note: There is no 5 ranking here as it is assumed there are always some external factors influencing growth.
Source: Authors.

From the example, the impact on property values is significantly linked to poor sanitation. Therefore, a linkage value of .6 is selected.

Considering the above variables, it is shown that some of the realized increases in property values after the implementation of the project can be attributed to FSM. This is shown through the spillover valuation calculation using the formula:

$$\textit{Spillover Value} = (G_a - G_0) \times I \times C \times L,$$

i.e., Spillover Value = (8% – 1%) × .73 × .6 × .6 = 1.85% per year.

This means that of the growth in property values and property tax collections, 1.85% of the 7% growth for this parameter can be attributed to the FSM program intervention. The same strategy can be used for the other parameters to obtain the full economic picture of the spillover effect.

4.5 How to Use This Information

Up until now, the discussion has been about citywide improvements. The spillover effect can also be measured locally. Consider the real estate along the first two streets fronting the bay at Dumaguete City. For every $25 million of real estate valuation, 1.85% per year of property value growth can be attributed to the fact that there is a functioning FSM program in the city. By the tenth year of the project, this value amounts to almost $0.75 million—and that is just one parameter evaluated.

This information can be transferred to other cities interested in implementing FSM projects, which can utilize trends for the various parameters from Dumaguete City. As more cities develop their FSM programs and more data are accumulated over time, more accurate trend lines can be established.

4.5.1 Health

For communities influenced by waterborne disease outbreaks, the external spillover effects from environmental health improvements realized through citywide sanitation projects can be significant. Schistosomiasis, for example, is an infection by a parasitic worm and one type of waterborne illness tracked by most local health departments in Asia. Research indicates that there is a correlation between water supply and sanitation and the prevalence of this disease. Programs that improve sanitation and at the same time reduce the disease incidence would see (i) reductions in the amount families spend on medical care, and (ii) reductions in lost time due to illness and therefore greater productivity. Gastrointestinal cases in addition to schistosomiasis are tracked in Dumaguete (Table 4.6).

Table 4.6: Number of Gastrointestinal Cases per Year in Dumaguete City, 2005–2017

Year	No. of Gastrointestinal Cases
2005	483
2006	No data
2007	1,288
2008	373
2009	1,853
2010	724
2011	695
2012	647
2013	304
2014	360
2015	322
2016	637
2017	553

Source: City of Dumaguete Planning Office, 2017.

In Dumaguete City, the public market is a major generator of wastewater in the downtown business district that drains to the bay. The bay is used for recreational swimming by locals and some seafood production. In 2006, through the assistance of the Bremen Overseas Research and Development Association (BORDA), a wastewater system for the public market was constructed and put into operation. There was an immediate reduction in wastewater entering the bay. The operations of the wastewater treatment plant were intermittent during the first few years, until in 2010 when the fecal sludge treatment plant came online, and the market wastewater system was fully functional. Pollution entering the bay was drastically reduced. This corresponds to low levels of waterborne illness. The improved environmental health can be seen in the health data. In 2007 and 2009, incidence of gastrointestinal diseases was high, which may be due to the fluctuating operation and maintenance of the wastewater system at the public market during that time period.[4]

Note the rise in cases starting in 2016 showing that there is a general increase in gastrointestinal diseases reported. This may be related to the deterioration of the public market wastewater system that occurred at around this time. While funding has been appropriated for repairs, no action has been taken due to political opposition to the project regarding the continued operation of the wastewater system in the park across from the market.

4.5.2 Net Present Value of Spillover Benefits in Dumaguete

To estimate this FSM project's economic spillover effects on local economic performance, city-level data are used, where the parameter of "annual regular income" is the indicator of local GDP and real property tax is an indicator of property value, which is provided by the Bureau of Local Government Finance. In this way, the net present value (NPV) of the spillover effects on local economic development and property values can be examined. Similar to the discussion on property values above, the estimation uses the same formula as:

$$\textit{Spillover Value} = \textit{Initial Value} \times (G_a - G_0) \times I \times C \times L,$$

where

- *Initial Value* refers to the value of the parameter in the base year 2009;

[4] Basic Needs Services Philippines Incorporated. DEWATS for Dumaguete Public Market. https://bnsphils.wordpress.com/projects-implemented/dewats-for-dumaguete-public-market/ (accessed 20 March 2018).

- is the annual growth rate of the FSM project from 2010 to 2016;
- is the average pre-project growth rate from 2010 to 2012;
- *I* represents the degree that the parameter is affected by poor sanitation;
- *C* refers to the likelihood that the intervention will improve the condition; and
- *L* is the linkage of the intervention and the growth of the parameter.

Also, to make the estimation of the economic effect of the FSM more concrete, a benefit–cost analysis is employed by calculating the NPV of the spillover effects and comparing it to the project initial cost.

The estimation results of the spillover values and NPV are shown in Table 4.7. We can see that there is a large increase in GDP growth and property tax value from 2013 comparing the mild growth in 2010–2012, which just shows there is a 3-year lag period of the FSM project to have tremendous economic spillover effects. On the other hand, by estimating the NPV and comparing it to the project's initial cost (approximately $500,000), the whole-period NPV of GDP growth spillover value is 4.55 times higher than the initial cost, and the estimation results show that it takes only four years to pay back the initial cost considering the NPV of GDP growth spillover value. On the other hand, the whole-

Table 4.7: Spillover Values and Net Present Value of Fecal Sludge Management Project in Dumaguete City

	Year						
Spillover Value	**2010**	**2011**	**2012**	**2013**	**2014**	**2015**	**2016**
GDP growth	$87,517	$287,617	$224,404	$389,627	$618,314	$859,519	$1,080,719
Property tax	$10,867	$11,743	$21,793	$36,269	$23,277	$25,985	$33,275
		NPV Value				**Ratio to Initial Cost**	
NPV (GDP growth, 7-year)		$2,277,229				4.55	
NPV (Property tax, 7-year)		$111,203				0.22	
NPV (GDP growth, 4-year)		$771,673				1.54	
NPV (Property tax growth, 7-year)		$662,148				1.32	

GDP = gross domestic product, NPV = net present value.

Note: The unit of spillover value and NPV is $1; the discount rate used in calculating NPV is the social discount rate of 9% from the Asian Development Bank; and the initial value used in the estimation of the spillover effect value and NPV is $7,308,866 for annual regular income and $311,022 for the real property tax. All these values have been transformed into United States dollar from Philippine peso using an exchange rate of $0.02 = ₱1.00. The initial cost of the fecal sludge management project is $500,000.

Source: Bureau of Local Government Finance.

period NPV of property tax spillover value is about 22% of the initial cost which is not as high as GDP growth spillover value. However, if we only consider the pure increase of the property tax, the estimation shows that the whole-period NPV of property tax growth is 1.32 times higher than the initial cost, which is still a plausible result. Therefore, the empirical results suggest that the FSM project in Dumaguete City has been positively affecting local economic development and capital values, which gives additional evidence of the benefit of infrastructure investment in Dumaguete City.

4.6 Estimating the Internal Effect Values through Co-treatment in Project 7

To continue the discussion of full valuation of FSM projects, we have already discussed the capital and operational expenses, as well as potential spillover effects. There are also internal savings that can be realized through smart management that we call the internal effect. One method of smart management is co-treatment, or the management of fecal sludge and septage along with municipal sewerage.

Maynilad Water Services Incorporated (MWSI) maintains a fleet of 10-cubic-meter desludging trucks, each costing the equivalent of about $120,000.[5] In Manila, septic tank volumes vary widely depending on the size of the property and wealth of the family served by the tank. In the Project 7 area, the estimated volume of residential septic tanks is just under 2 cubic meters. For commercial and institutional septic tanks, the estimated volume is approximately 6.5 cubic meters. The procedure is for the truck operators to bring full loads to the septage treatment facilities, which means that typically more than one septic tank is desludged to fill the truck prior to bringing the load back to the treatment plant. MWSI utilizes private sector contractors to operate their trucks. The 2018 rate of the private sector operator is approximately $8 per cubic meter for the septage collected and transported, which includes the costs for drivers, helpers, fuel, and operation and maintenance of the truck.

Prior to the commissioning of the Project 7 co-treatment plant, all septage collected from MWSI customers was transported to the Dagat-Dagatan septage treatment plant. Trucks on average were able to make one complete trip per day. This includes (i) driving from the

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[5] Philstar. 2013. Maynilad Inaugurates P266 Million Sewage and Septage Treatment Plant. 19 October. https://www.philstar.com/business/2013/10/19/1246787/maynilad-inaugurates-p266-m-sewage-and-septage-treatment-plant (accessed 20 March 2018).

truck yard to the first septic tank to be desludged, (ii) desludging that tank, (iii) driving to the next building to be desludged, (iv) desludging that septic tank, (v) continuing to desludge additional tanks until the truck is full, (vi) driving to the treatment plant, and (vii) driving back to the truck yard. With the advent of Project 7, drive times were greatly reduced allowing for each truck to make two complete trips per day on average. This greater efficiency resulted in significant savings from the collection activities as the number of trucks (and their drivers and helpers), fuel, and other operational expenses were reduced.

The design capacity for septage acceptance at Project 7 is 240 cubic meters per day (Table 4.8). However, current average daily flow is 110 cubic meters per day. This is in part due to low acceptance by the customers, which in turn is due to lack of knowledge about the septage programs on the part of the building owners, as well as the inability to desludge the tank in some cases due to access or inability to locate it. As more of the cities within the coverage area adopt local ordinances on septage management, and as promotional campaigns promoting the service are stepped up, the actual daily septage volumes delivered to the plant is anticipated to approach the design flow.

The number of persons served by Project 7 is shown in Table 4.9. MWSI projections achieve full sewerage connectivity for the coverage area by 2037.

Table 4.8: Data Input Values of Maynilad Water Project 7

Residential septic tank volume	1.7 m^3
Commercial septic tank volume (average)	6.5 m^3
Desludging frequency (building not connected to combined sewer)	5 years
Desludging frequency (building connected to combined sewer)	7 years
Working days per month	25
Crew hours per day	10
Assumed cost for trucking operation and maintenance	$8 per cubic meter desludged (does not include cost of trucks)
Truck cost	$120,000
Truck volumetric capacity	10 m^3
Number of full loads per day prior to project	1
Number of full loads per day after project	2
Treatment plant design capacity for septage	240 m^3

m^3 = cubic meter.

Source: Interviews with Maynilad Water Services Company staff, 2017.

Table 4.9: Number of Persons Served by Project 7

Currently served: residential tanks	65,000
Maximum residential tanks at full capacity	195,500
Currently served: commercial/institutional tanks	9,750
Maximum commercial tanks at full capacity	29,775

Source: Interviews with Maynilad Water Services Company staff, 2017.

4.6.1 Estimates of Savings

The impact of Project 7 in terms of desludging costs is significant. Due to the added septage delivery location, the trucking operation has become more efficient. Each septage truck is now expected to make two full trips per day delivering 20 cubic meters per truck per day. That is twice the delivered volume of septage that went to Degat-Degatan prior to the commissioning of Project 7. Twice the efficiency of the trucking operation means that only half of the prior number of trucks are required to do the job, resulting in half the cost of the trucks and related fleet expenses, which breaks down as shown in Table 4.10.

Table 4.10: Savings of Maynilad Water Project 7

	1 Year	10 Years	20 Years
Fuel savings (assuming truck uses 8 liters per hour)	$130,680	$1,306,800	$2,613,600
Truck savings (assuming 10-year depreciation)	$33,825	$338,250	$676,500
Operation and maintenance of fleet	$129,406	$1,294,061	$2,588,122
Total	**$293,911**	**$2,939,111**	**$5,878,222**

Source: Interviews with Maynilad Water Services Company staff, 2017.

The septage treatment components of Project 7 are estimated at about 25% of the total cost of the facility, or approximately $1.4 million. Therefore, the spillover effect savings over 20 years are more than three times the CAPEX for the septage equipment, solely through fleet management savings.

As shown, the internal benefits of co-treatment for Project 7 are significant. In the coming months, the project team will collate data on increases in tax revenues and health impact to estimate the spillover effect in Quezon City, similar to what was performed for Dumaguete City.

4.7 Conclusion and Policy Implications

The spillover effect is real and significant, as demonstrated by the citywide FSM project in Dumaguete City. The effect comprises increases in property value and tax revenue, livelihood, health, and economic development. Policy makers are reluctant to support FSM projects that typically report lower benefits in ex ante and ex post project evaluations. Quantifying the spillover effect of FSM projects makes it easier to persuade policy makers to accelerate such projects. More importantly, with a better understanding of the spillover effects, policy makers can also persuade prominent beneficiaries, such as resort owners and businesses to pay high user charges to cover the recurrent costs to sustainably operate FSM projects.

A toolkit (under development) will simplify the process for city officials and policy makers through an interview style platform that they can use to adjust the variables based on likely but conservative values for their cities. As more cities enact FSM projects and collect data, trend lines both before and after project implementation can be established, which can be used by other cities as they estimate their own potential spillover effect valuations as they develop their own FSM projects.

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5

Socioeconomic Spillovers Resulting from the Functioning of Sewage Treatment Plants in Jaipur, India: A Case Study of the Delawas Plant

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5.1 Introduction

5.1.1 Sectoral Overview

As per the 2017 Joint Monitoring Programme (JMP) report by the World Health Organization (WHO) and the United Nations Children's Fund (UNICEF), the progress on drinking water, sanitation, and hygiene across the globe suggests that 4.5 billion people, or 6 in 10 people worldwide, still lack safely managed sanitation, and 2.1 billion, or 3 in 10 people worldwide, lack access to safe, readily available water at home.

By 2015, 181 countries had achieved over 75% coverage with at least basic drinking water services and 154 countries had achieved over 75% coverage with basic sanitation services. Unsafe sanitation is one of the biggest challenges that developing nations are facing today (Araral and Ratra 2016). This is due to unsafe water, poor hygiene practices, and inadequate sanitation. Inadequate sanitation leads to pneumonia, neonatal disorders, and diarrhea, some of the significant contributing factors in mortality in children under 5 years (UNICEF 2017). In many developing countries including India, the prevalence of open defecation has a terrible effect on children: it exposes them to illnesses that cause malnutrition and stunt their growth (UNICEF 2008).

It is estimated that about 62,000 million liters per day (MLD) of sewage is generated in urban areas in India, while the treatment capacity across India is only about 23,277 MLD, or 37% of the total sewage generated, as per the data released by the central government in December 2015 (Mallapur 2016). This means that about 63% of sewage generated in urban India is not treated and is randomly dumped in rivers, seas, lakes, and wells, polluting three-fourths of the country's water bodies. As per government records, only 522 out of 816 sewage treatment plants are operational (CPCB 2015). The operation and maintenance (O&M) of the existing treatment capacity is also not very good, or below par, with almost 39% of plants not conforming to environmental rules for discharge into streams. For example, in Jaipur, total wastewater generation is approximately 378 MLD according to the Rajasthan Urban Infrastructure Development Project (RUIDP), whereas existing capacities of sewage treatment plants (STPs) are only 235 MLD (i.e., 62%). Similarly, Bangalore generates 1,400 MLD of wastewater, according to Bangalore Water Supply and Sewerage Board (BWSSB) sources, but the total treatment capacity is 721 MLD and only 520 MLD gets treated on average (Urban Waters 2018).

In India, the central government, under the leadership of Prime Minister Narendra Modi, has taken on the task of sanitation as a key mission. The Ministry of Urban Development has taken various steps in eradication of open defecation and launched various schemes:

1. Swachh Bharat Mission (SBM), with an aim to eradicate open defecation across India by 2 October 2019, the 150th birth anniversary of Mahatma Gandhi, the father of the nation, by universalizing construction and usage of toilets.
2. Atal Mission for Rejuvenation and Urban Transformation aimed at strengthening the sewerage and water supply network of the country.
3. Faecal Sludge and Septage Management Policy, 2017 (Ministry of Urban Development 2017), whose key objective is to set the context, priorities, and direction for, and to facilitate, nationwide implementation of fecal sludge and septage management services in all urban local bodies such that safe and sustainable sanitation becomes a reality for all in each and every household, street, town, and city.

5.1.2 Rajasthan Scenario

Rajasthan is one of the largest states in India, strategically located with an area of 342,239 square kilometers and a population of 68.89 million as per the 2011 Census. The state has less than 2% of the country's groundwater and surface water resources. Inland water resources are 0.30 million hectares with rivers and canals stretching to 5,290 kilometers (Ministry of Statistics and Programme Implementation 2016).

Low and erratic rainfall in Rajasthan characterizes it as the most water-deficient and one of the driest states in India. It receives about 574 millimeters (mm) average annual rainfall, ranging from 100 mm (lowest in the state) in Jaisalmer and 550 mm in Ajmer to 1,638 mm (highest in the state) in Mount Abu (Mundetia and Sharma 2014). Out of the 222 schemes supplying water to the urban towns of the state, 14 (or 7%) depend on surface water, 54 (or 25%) on both surface and groundwater, and the remaining 156 are entirely dependent on groundwater (RUIDP 2016). According to the Central Ground Water Board of India, groundwater reserves in 164 of the Rajasthan state's 249 blocks are "overexploited," while they are "critical" or "semi-critical" in 37 others (CGWB 2017). Rajasthan state has always faced water scarcity. At least 24 main cities and towns of the state had tap water supply only once in four days; this is a major issue faced by the people in the state.

Trends in Urbanization

While the urban population of Rajasthan is around 25%, or 17 million, the state has the lowest range of urbanization compared to others in India and the national average. Urban water supply is one of the most critical elements of urban infrastructure. Water is a basic necessity, which directly impacts the health and well-being of society as a whole. More than 50% of past investments in urban infrastructure have been in the water sector. The sector has evolved over time and dependence on groundwater is decreasing, with municipalities shifting to surface sources of water. Similarly, there is a shift from intermittent supply to constant water supply projects in a few areas.

The 2011 Census classifies toilets as either water closet, pit latrine, or other latrine types. The statistics for Rajasthan are similar to the national average: 73% of households have water closets and almost 18% do not have access to a toilet facility. With respect to the wastewater situation, the state is behind the national average; only 25.6% of households are connected to a piped sewer system and almost 17% dispose of their sewerage in the open. For treatment purposes, there are 63 sewage treatment plants with a total capacity of 865.92 MLD. Of these, 11 plants with a capacity of 149.3 MLD are under construction and about 36 plants with a capacity of 322.12 MLD are in the planning stage and proposed to be constructed soon, as per the draft policy on fecal sludge and septage management of the Rajasthan government (RUIDP 2017). The responsibility of sanitation in urban areas rests with urban local bodies, capital investments in sewerage and other sanitation sector infrastructure come mainly through the state government, and the responsibility for O&M lies with the respective urban local bodies.

5.1.3 Jaipur City Profile

Jaipur city is surrounded by the Nahargarh hills in the north and the Jhalana hills in the east, which are part of the Aravalli range. To the south and the west of the city are also prevailing hillocks, but they are isolated and discontinuous in formation.

Also called the pink city of India, Jaipur ranks 10th among the country's megacities with an annual growth rate of around 5% between 2001 and 2011. The city has a population of 3.1 million and is a popular tourist destination, with about 3,000 tourists visiting the city daily. The city's economy is primarily based on trading, administration, tourism activities, and local handicrafts. Given this urban heritage and its status as the state capital, Jaipur has been the central focus of the state government's vision and strategies; hence, efforts have been made to develop it into a "world-class" city. According to the Jaipur Municipal Corporation (JMC), the city is expected to undergo massive urban restructuring following its inclusion in the Smart City Program.

Water Scenario

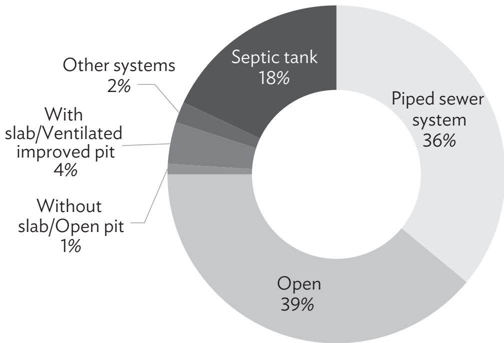
The city is currently experiencing growing water scarcity and diminishing drinking water sources. The groundwater level in the city has declined by 25 meters in the last decade. The Central Ground Water Board has declared all 13 blocks in the city as dark zones. From 2004 to 2014, the groundwater table in Amber block fell 23.18 meters. Officials maintained that the withdrawal rate of groundwater is almost 200% more than the rate at which this source is getting recharged. The situation is alarming, especially in the urban areas (CGWB 2017).

Wastewater Management in Jaipur

The city counts among the most unhygienic cities of the country with a rank of 215 among the 434 cities in the government's latest Swachh Sarvekshan survey of 2017(Ministry of Housing and Urban Affairs 2017).

The status of sanitation coverage of Jaipur city as per the 2011 Census is depicted in Figure 5.1. With total wastewater generation of approximately 378 MLD, the existing capacity of the STPs operating in the city is only 235 MLD (Table 5.1) or 62% of the requirement of the city, as per the information provided by RUIDP.

Figure 5.1: Sanitation Coverage of Jaipur City



Source: Indian Census 2011.

Table 5.1: Functional Sewage Treatment Plants in Jaipur

No.	Location	Year of Commissioning	Installed Capacity (MLD)
1	Delawas-I	2006	62.5
2	Delawas-II	2011	62.5
3	Jaisinghpura Khor	2011	50.0
4	Amer Road	2006	27.0
5	Jawahar circle	2010	1.0
6	JDA Ramniwas Garden	2014	1.0
7	Vidyadharnagar	2014	1.0
8	Gajodharpura	2013	30.0
		Total	**235.0**

MLD = million liters per day.

Source: Jaipur Municipal Corporation.

Delawas STP

The project was initially taken up by RUIDP under funding from the Asian Development Bank (ADB) and covered 42,000 properties. The sewerage management of the entire city was planned and proposed to be conducted in two phases: Jaipur Sewerage Project Phase I entrusted to the Jaipur Development Authority and Sewerage Project Phase II entrusted to JMC (Centre for Innovations in Public Systems, ASCI Hyderabad 2014).

Phase I

The first phase involved constructing STP Unit I at Delawas, which has a capacity of 62.5 MLD, an anaerobic digester with a centrifuge unit, and a biogas bottling plant. The plant at Delawas was constructed by RUIDP under an ADB-funded project in Phase I. The objective of the establishment of the Delawas STP was to ensure proper management of wastewater and to follow the wastewater disposal standard set by the state and central pollution control boards after treatment.

Safe disposal will also reduce the spread of various diseases caused by pathogenic organisms present in sewage (Arceivala and Asolekar 2006). On the economic front, gainful reuse of the effluent and stabilized sludge was planned, among others, for agriculture and for power generation for the STP by establishing a biogas plant.

Present Status

VA Tech Wabag Ltd. Chennai constructed and also has conducted O&M of the plant since 1 September 2006. A power generation plant, installed under the government's Jawaharlal Nehru National Urban Renewal Mission (JNNURM) modernization scheme, has been operational since 2009. Daily generation of biogas during sludge digestion is approximately 6,000 cubic meters (m^3), and the total digested sludge generated is about 55–60 m^3 per day .

The initial construction and O&M package cost was about ₹140.6 million, including the cost of power connection and third-party inspection by an external agency at about ₹6 million and ₹18 million, respectively, for 5 years O&M. The total land area available for the plant is about 94 *bigha*,[1] and the treatment technology is an activated sludge process with an anaerobic digester and centrifuge unit (no sludge drying beds). The O&M cost of the Delawas STP estimated by Jangid and Gupta (2014) was about ₹1.62 million–1.67 million during the first year of the O&M contract after commissioning in 2006, which included ₹1.354 million–1.4 million toward power charges and ₹266,000 for the O&M contractor. This O&M cost escalated to ₹2.10 million–2.24 million in its fifth year, including ₹1.75 million–1.90 million toward power charges and ₹336,000 for the O&M contractor.

Phase 2

In the second phase, another 62.50 MLD STP and power generation unit was constructed by Jaipur Nagar Nigam in 2009/10 under

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[1] A *bigha* is equal to 1,618.7 square meters.

JNNURM. The power generation unit constructed under this phase produces about 7,000 units of power per day from the gases produced during digestion of sludge at the existing plant. This is an example of waste to energy, with savings of about ₹1.2 million–1.3 million in power charges every month during plant operation.[2] The treated wastewater from the Delawas STP is being used for agriculture and industrial purposes after further treatment. Besides Unit II of the 62.5 MLD Delawas STP (Pratapnagar), JMC has also constructed a 50 MLD unit at the Jaisinghpura-Khor STP under this phase.

5.2 Assessment of Socioeconomic Issues before Commissioning of the Delawas Treatment Plant

5.2.1 Risks Associated with Using Untreated Wastewater for Irrigation

a) **Public Health**

The focus was on waterborne diseases, infant and child mortality rates, diarrheal diseases, and so on.

i) No substantial data could be retrieved in this regard either at primary health centers or dispensaries or with any government officials.

ii) During the survey with villagers in Ramchandpura, no major issues were found prior to the Delawas STP developmental interventions.

b) **Environmental Impacts**

The focus was on groundwater contamination and foul odor.

i) Before 2003, only household or domestic wastewater was discharged in Amanishah Nallah; there was no industrial waste.

ii) Also, the open side drains were regularly blocked by waste dumped by households giving an unhygienic appearance across the city.

iii) Before the commissioning of the Delawas STP, sewage was treated using a self-cleansing process because the wastewater used to travel for more than 17 kilometers (to Ramchandrapura village where it was used for farming),

[2] According to records of plant operations at the STP site office of VA Tech Wabag Ltd., Jaipur.

thus leading to a substantial decrease in biological and chemical oxygen demand.[3]

iv) In 2003, after the Rajasthan Industrial Investment Cooperation Organization (RIICO) set up operations in the area, industries came into existence. The water discharged into the nallah was contaminated and contained harmful chemicals. The water quality was highly polluted but there was no method to treat this toxic waste.

v) This mixture of industrial and domestic wastewater was directly discharged in Amanishah Nallah through a 1.8-meter diameter outfall sewer at Delawas, which was dumped into the Dravyavati river.

vi) Diseases of the intestine and stomach increased in Jaipur city as the market saw an influx of vegetables grown in these areas using untreated sewage.

vii) The wastewater, however, was used in intermediate villages such as Ramchandrapura for farming. The chemical-rich (sodium, phosphorus, potassium) wastewater reduced use of manure or fertilizer by the farmers, thus increasing their profit.

viii) A study carried out by Rajasthan University and SMS Medical College Jaipur during that period established that heavy metals such as cadmium, chromium, and lead, which were present in the wastewater, were also present in the vegetables irrigated in these areas, including Nevta Ka Bandha, Chandlai dam, Lakhawaska Bandha, Chilki Doongri, Ramchandpura, Chaksu ka Bandha, Bandhkhera ka Bandha, and many more.

ix) Under the above referred study on heavy metals contamination of vegetable foodstuff in Jaipur, samples were collected from four sites—Amanishah Nallah, Sanganer industrial area, Malviya Nagar industrial area, and Bais Godam industrial area—over a period of 2 years between 2005 and 2007. These samples were tested using atomic absorption spectrophotometry at the Geological Survey of India (GSI) laboratory in the city. The results indicated that the consumers were purchasing vegetables containing high levels of heavy metals (Times of India 2015).

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[3] According to an executive engineer of JMC.

x) Contamination and deterioration of groundwater quality due to untreated sewage was reported from various sources of water.

xi) Informal discussions with JMC officials and residents of the affected areas during the survey revealed that the Sanganer Dam was demolished after the 1981 floods. The demolition of the dam led to the formation of the Dravyavati River. Between 1981 and 1990 (until the dam was built), the farmers used the surface water from the river to irrigate their fields. During this period, the groundwater table was maintained at around 60–70 feet. However, after 1990, farmers had to switch to underground sources such as tube wells for the purpose of irrigation, which led to a heavy fall in the groundwater table up to 200 feet. Since the groundwater of southern Jaipur contains a lot of heavy metals, the use of this groundwater led to hardening of the soil, thus leading to low crop yields. After 1995, however, the farmers began to use the wastewater that was flowing in Amanishah Nallah. This use of untreated sewage, which consists of nutrients like sodium, potassium, and phosphorus, softened the soil as well as increased crop yields. After 2000 and the subsequent development of RIICO and others in the area, the groundwater table further decreased up to 400 feet.

xii) Also, the untreated wastewater flowing along Amanishah Nallah continued causing a strong foul smell in the surrounding areas.

c) Economic Losses

The survey of communities revealed an interesting trend. The farmers who were using untreated domestic wastewater prior to the commissioning of the STP, due to the high contents of soil nutrients such as nitrogen, phosphorous, and potassium, had increased their vegetable yields and consequently their revenues.

The farmers in the nallah area are nearby residents who have encroached the land and have been growing vegetables for several years. The high court imposed a ban on growing, or rather irrigating, the vegetables using the nallah water, as this had become a major public health threat to the urban population due to use of water contaminated with industrial waste resulting in an increase of heavy metals in the vegetables. The high court ban gave rise to loss of revenue for the farmers.

d) Land and Property Values

i) The land and property values as discussed with communities were very low prior to the interventions; no substantial infrastructure development took place in the area. In fact, land values were lower than that of adjoining areas such as Pratap Nagar and Vatika. Land prices rose substantially following the establishment of RIICO in 2003.

ii) However, there was a strong stench all around the path along which the wastewater used to run. Few people used this water on their farms, and even fewer people settled around the Amanishah Nallah, thus leading to low land rates and low business income—as the sole source of income in 1988 when the nallah emerged was farming. Since people did not want to settle in a foul-smelling location, the rate of infrastructure growth slowed. Also, the crops grown using the wastewater tended to rot more quickly than those using fresh water and led to diseases of the stomach and intestine.

5.3 Government Initiatives and Policies: An Overview of the Delawas Treatment Plant

The Rajasthan Urban Infrastructure Development Project (RUIDP) was established by the state government in 2000 to develop key urban centers using ADB financing. The first phase of the RUIDP program took up six divisional headquarter cities (Ajmer, Bikaner, Jaipur, Jodhpur, Kota, and Udaipur), to benefit a population of 7.7 million by 2011. The works covered were related to water supply, wastewater management, drainage, strengthening of the roads, construction of rail over bridges and flyovers, solid waste management, slum improvement, fire-fighting, medical and health, and heritage preservation. The total project cost was about $362 million for the first phase, shared between ADB ($250 million) and the state government ($112 million).

The formation of RUIDP led to the implementation of the STP. The project was undertaken by the Government of Rajasthan as a special purpose vehicle with support from the Government of India and ADB in 1998. Implementing agencies were the Urban Development and Housing Department, urban local bodies, and the Public Health and Engineering Department, Rajasthan, with support from the development authorities, urban improvement trusts, and RUIDP (RUIDP 2015).

The STP project at Delawas was implemented by RUIDP and later handed over to JMC for O&M and expansion—or rather development of the second unit. The units are technically identical except that in the last stage the first unit produces biogas and the second unit generates electricity. Both units have a commissioned capacity of 62.5 MLD each. The first unit was funded by ADB and the second unit under JNNURM.

5.4 Survey on Socioeconomic Spillovers Resulting from the Functioning of the Delawas Treatment Plant

To understand the socioeconomic spillovers a survey was completed of residents, farmers, local vendors including vegetable sellers, dairy and milk sellers, and *sarpanch* (village head) in the surrounding colonies. Data were collected in Hindi language for about 182 households.

The following villages and peri-urban areas were covered:

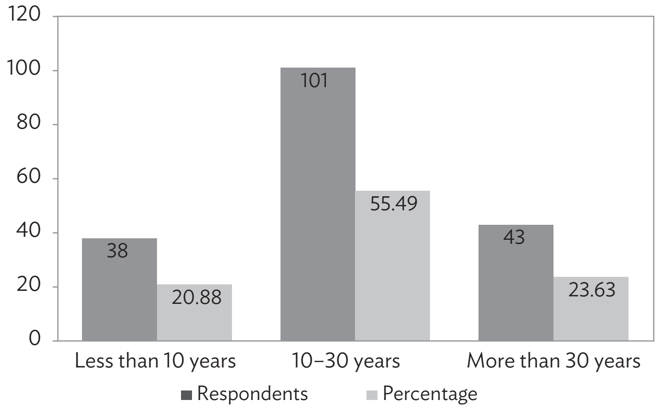
1. Gharonda
2. Bambala
3. Ramchandrapura
4. Rampura
5. Vidhani
6. Mathurawala

The survey collected the following information:

a) Basic demographic data including
- i) Name of the farmer/resident
- ii) Gender/age
- iii) Area/village name
- iv) Distance from plant
- v) Date of survey
- vi) Mobile number for future correspondence

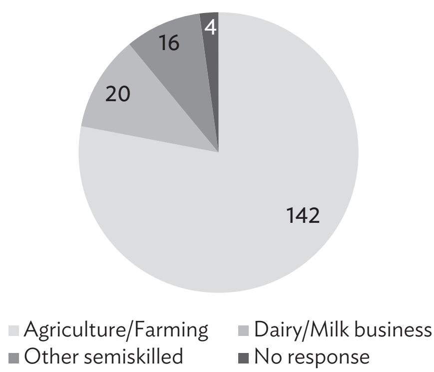
b) Socioeconomic survey
- i) How many years have you been living here?
  - a) Less than 10 years:
  - b) 10–30 years:
  - c) More than 30 years (responses depicted in Figure 5.2)
- ii) How long have you been practicing agriculture or farming?
  - a) The majority of residents (almost 80%) were farmers (Figure 5.3), growing crops such as wheat, barley, millet, and sorghum. The yield of wheat has increased when using treated effluent but reportedly not high if using the underground water which has high total dissolved solids (TDS; 2,000 milligrams per liter) and high fluoride contents.

Figure 5.2: Length of Time of Residence in the Area (%)



Source: Survey conducted by the Manipal University Jaipur team.

Figure 5.3: Profession of Residents
(no. of respondents)



Source: Survey conducted by the Manipal University Jaipur team.

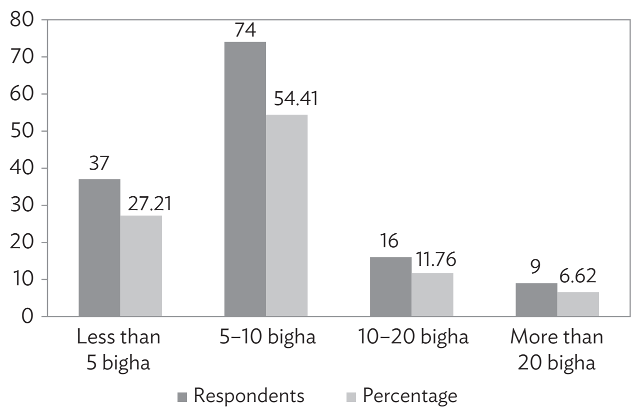
b) Reverse osmosis plants are installed in villages such as Vidhani, Mathurawala, and a few others. The filters of such plants at these villages are choked every month and have to be replaced frequently. Villagers have to pay ₹150 per month for 25 liters of filtered water per day. Cards are issued to residents. More water means more money has to be paid for the card.

c) Vegetable farming is not allowed as per a high court decision, but farmers are growing some for own use and a few also for selling. The main vegetables are brinjal, cauliflower, tomato, and onion. Chili plants are grown, but crop yields are low, so they do not grow chilies.
d) About 11% of farmers have established their own small business such as a dairy or milk business.
e) Economic conditions have improved. Respondent's apprehensions are that the Delawas STP effluent may be discontinued or diverted due to the new Dravyavati river project.

iii) What is the total land you possess?
a) Landholdings vary from 3 to 25 *bighas* (Figure 5.4).
b) There has been a steep rise in land prices after the commissioning of the STP.

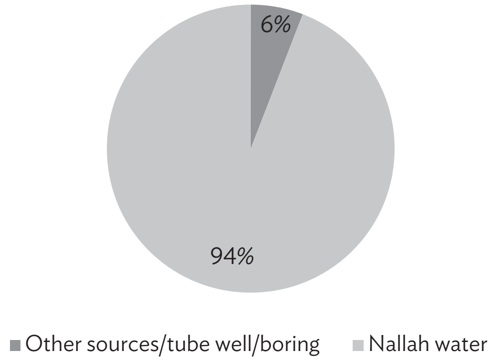
iv) What is the main source of water for your agricultural land?
a) Almost everyone (90%–100%) was using nallah water (Figure 5.5).
b) The groundwater table has gone very deep; as of 2018 the depth was 400–450 feet (Figure 5.6). This is the information provided by the residents as per their observations when wells are being bored in the area.
c) There are issues of fluoride and high TDS in groundwater.

Figure 5.4: Land Owned by Residents



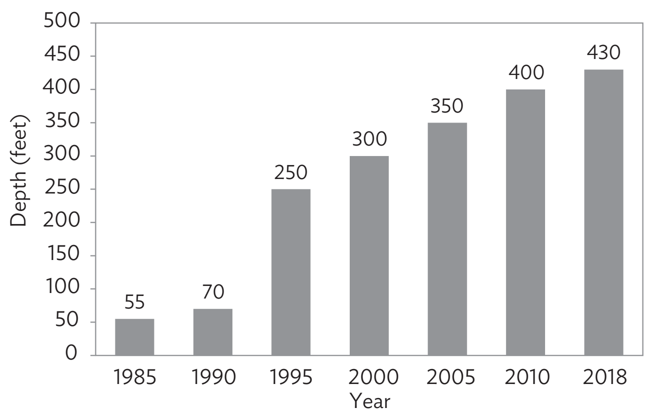
Source: Survey conducted by the Manipal University Jaipur team.

Figure 5.5: Source of Irrigation
(no. of respondents)



Source: Survey conducted by the Manipal University Jaipur team.

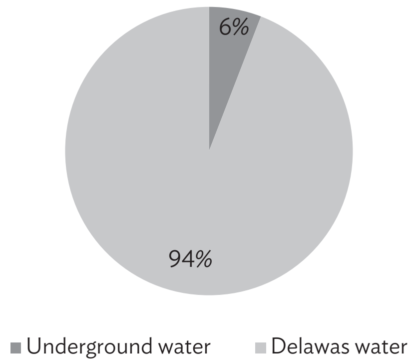
Figure 5.6: Groundwater Depth since 1985



Source: Survey conducted by the Manipal University Jaipur team.

v) Are you using the Delawas STP water for irrigation?
  a) Almost everyone was using the STP water.
vi) If yes, has using this water benefited crop yield?
  a) Of the respondents, 95% said they have benefited from using this water.
  b) Very few are using groundwater (Figure 5.7).

Figure 5.7: Source of Irrigation Water Used by Local Farmers
(no. of respondents)

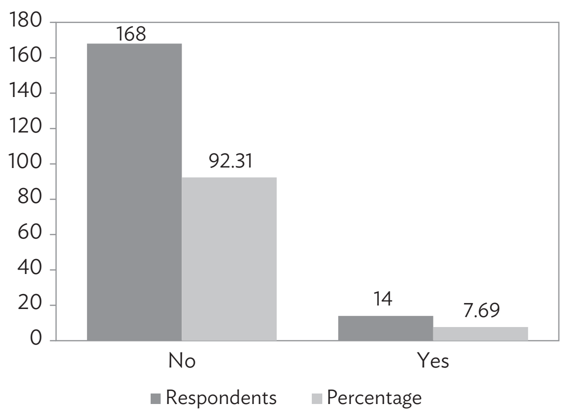


Source: Survey conducted by the Manipal University Jaipur team.

vii) Were there any losses or damage to your crop (insects, pests, etc.)?
   a) There was no loss to crop or damage; almost everyone responded in the same way.

viii) Is there any issue of bad odor?
   a) There was no issue with bad odor, as reported by 93% of people (Figure 5.8). Around the nallah, there was some issue with foul odor.

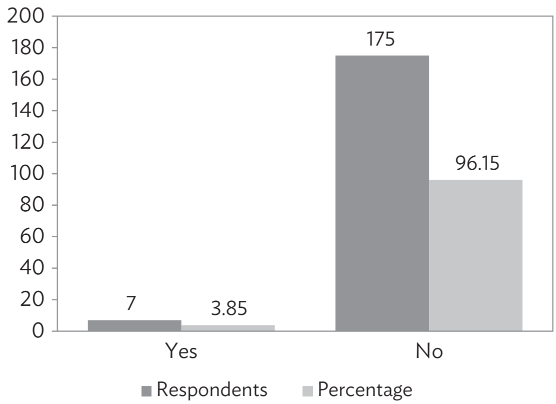
Figure 5.8: Bad Odor Issues



Source: Survey conducted by the Manipal University Jaipur team.

ix) Do you use manure produced by the Delawas plant?
   a) Very few use manure produced by the plant (Figure 5.9). They used it initially, but due to the high nutrient value the crops were overgrown and created problems.

Figure 5.9: Use of Manure Available from the Delawas Treatment Plant

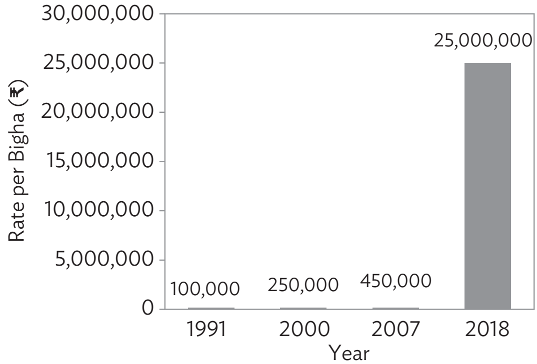


Source: Survey conducted by the Manipal University Jaipur team.

x) Has your economical and/or social status changed after the plant commissioning?
   a) Almost everyone said that there was an increase in their income after using the plant water.
   b) Social conditions have also been enhanced. People of other areas have started building social relations with the people of these villages.
   c) Land prices have increased substantially.
   d) A few farmers have even sold their land at a higher cost and moved to other areas.

xi) Do you think commissioning of the plant has increased the real estate prices in surrounding areas?
   a) Land prices have increased substantially.
   b) Many people in possession of RIICO land sold it and moved to other areas that were bought for industry.
   c) In 1991, the land price was ₹1 lakh per bigha. The present price is hovering around ₹250–300 lakhs per bigha (Figure 5.10).

Figure 5.10: Increase in Real Estate Prices since 1991



Source: Survey conducted by the Manipal University Jaipur team.

5.5 Summary of Survey Results

5.5.1 Effect on Health

Diseases: No disease rates have been substantial in the area, including diarrhea and waterborne diseases. The underground sewerage system connected to the STP has eliminated direct contact of untreated waste with humans and animals.

Odor: The odor issue has appreciably been reduced in the area because of the STP and is only negligible.

5.5.2 Additional Income Generation

Local business incomes: Local business has increased in the area. With the elimination of unhygienic conditions due to the spread of wastewater in open drains and odor, many academic institutions have moved into the area (Poornima University, JECRC University, and other universities). This has increased construction activities, employment opportunities for skilled and semiskilled workers, private hostels for students, a few big hospitals, commercial outlets, and so on.

Real estate pricing: Land prices have substantially increased due to the direct STP commissioning as it created a hygienic environment free from wastewater and odor nuisance. In addition, the establishment of the RIICO industrial area has led to many industrial units, various academic institutions, and residential colonies settling in the area.

Social issues: Given the better hygienic conditions, more residential colonies and communities are emerging in the area. This is enabling people to interact and mix with each other.

5.5.3 Environmental Impact: Effect on Water Pollution and Greenhouse Gas Emissions

The STP is removing toxins, polythene, rubber waste, and other plastic-related toxins from the wastewater. It is also reducing the biochemical oxygen demand of the wastewater and making it useful for horticulture. Overall final effluent levels are well within permissible limits useful for agriculture and groundwater recharge. Raw sewage characteristics and final effluent quality are depicted in Tables 5.2 and 5.3, respectively. The bad odor has been reduced considerably, and there is no air pollution as such.

Table 5.2: Raw Sewage Characteristics at the Delawas Treatment Plant

pH	7.12
TSS	620 mg/l
COD	776 mg/l
BOD	320 mg/l
NH_3-N	32 mg/l
Total nitrogen	**56 mg/l**

BOD = biochemical oxygen demand, COD = chemical oxygen demand, mg/l = milligram per liter, NH3-N = ammonia, TSS = total suspended solids.

Source: Central Pollution Control Board Bhopal, 2015.

Table 5.3: Final Effluent Quantity at the Delawas Treatment Plant

pH	7.68
TSS	40 mg/l
COD	170 mg/l
BOD	27 mg/l

BOD = biochemical oxygen demand, COD = chemical oxygen demand, mg/l = milligram per liter, TSS = total suspended solids.

Source: Central Pollution Control Board Bhopal, 2015.

5.6 Economics of Generating Electricity from Biogas Plants and Gas-based Plants

According to discussions with JMC officials, both plants are self-sustained. They are producing biogas and electricity with the help of Brijdham Power Private Limited, Jaipur.

They are also producing compressed natural gas (CNG) from this biogas plant and selling CNG cylinders (400 kilograms per cylinder). The gas generated during digestion of sludge is about 5,500–6,000 m^3/day. The gas generated is being sold to Braj Gas, which filters the gas and extracts methane to pack in cylinders and sell them under the label of "biogas." On a daily basis, five to seven cylinders of CNG are produced. The cost is 10% less than the per kilogram price of commercial liquefied petroleum gas (LPG). The benefit of this gas is that it is natural and does not pollute the environment. It is 10% lighter than air, so there is no scope of mishap in case of leakage.

Digested sludge generation per day is about 55–60 m^3; inorganic matter from grit separation is about 16–18 m^3/day; and inorganic matter from fine and coarse screening is about 1.7–2 m^3/day.

In the first phase, the plan was to sell the gas to industries. Once large-scale production is achieved, it will be sold in the Jaipur market.

The power generation unit produces about 7,000 units of power per day from gases produced during digestion of sludge at the existing 62.50 MLD STP. This corresponds to savings of about ₹1.2 million–1.3 million in power charges every month, as per calculations from VA Tech Wabag Ltd, STP Delawas. Thus, the Delawas STP is self-sustaining with a monthly deficit of about ₹250,000, according to JMC estimates. The cost viability calculations of the Delawas STP—carried out by Jangid and Gupta in 2014 for a period of 10 years (2008–2017) by capitalizing (considering rate of interest as 15% per year) the project execution cost, annual O&M cost, and cost of power to be generated every year—suggest that the revenues generated through the selling of biogas and electricity for JMC would result in a cumulative savings of about ₹245 million.

5.7 Fate of Surplus Wastewater and Use of Manure

A total of 2.5 MLD treated wastewater is supplied directly to the NRI colony using pipes and tank storage. This stored water is used only for horticulture, thereby reducing the burden on natural groundwater resources. Also, the fields irrigated using wastewater require no manure as the wastewater already is high in sodium, phosphorous, and potassium. The remaining 120 MLD of water is supplied to Ramchandrapura and adjacent surrounding villages for irrigation. There are also other parks that have been using this water for plantation, and the remaining water is flowed back to Amanishah Nallah.

The use of manure has been limited in surrounding areas as all the nutrients are provided by the treated wastewater. Furthermore, the use of manure in turn appears to lead to overgrowth of crops resulting in quicker rotting of onions, cauliflower, and brinjal than the expected period of sustainability. Also, if wheat is grown using this manure, the plant instead of being erect (i.e., climber) starts acting like a creeper. Since there seems to be an overdose of nutrients in this manure, villagers are avoiding its use.

5.8 Conclusions

Jaipur city is expanding at a faster speed than anticipated. Hence, JMC is faced with the maintenance and expansion of the city's civic facilities to meet the growing requirement. Increased sewage treatment facility is critical to conserve water for future generations. The present total wastewater generation in Jaipur is approximately 378 MLD (as provided by RUIDP); the existing capacity of STPs operating in the city is only 235 MLD, or 62% of the requirement of city. Although this is better than the national average of 37% treatment capacity, Jaipur city ranked among the most unhygienic cities of the country (215th of the 434 cities in the latest Swachh Bharat ranking). Compare this with Indore city, which came in top in the 2017 Swachh Sarvekshan survey with an operational (under development) STP capacity of 335 MLD against a sewage generation of approximately 270 MLD, or 125% of the requirement.[4] This is indicative of the importance of sewage treatment in the overall ranking besides many other parameters.

Before commissioning of the STP, sewage was directly discharged in Amanishah Nallah through a 1.8-meter diameter outfall sewer at Delawas. Farmers were using this untreated sewage for growing vegetables, which were becoming harmful for people and increasing stomach and intestinal diseases. This has also reportedly led to a deterioration in the groundwater quality in these areas due to percolation of untreated sewage.

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4 See Indore Municipal Corporation website (http://www.imcindore.org/webindore/#).

The formation of RUIDP led to the implementation of the STP. The project was undertaken by the Government of Rajasthan as a special purpose vehicle with support from the Government of India and ADB in 1998. Implementing agencies were the Urban Development and Housing Department, urban local bodies, and the Public Health and Engineering Department, Rajasthan. The STP project at Delawas was implemented by RUIDP and later handed over to JMC for O&M and expansion. The first unit was funded by ADB and the second unit under JNNURM.

Commissioning and successful functioning of the two units of the Delawas STP of total 125 MLD capacity have changed the scenario in Jaipur city. The overall lifestyle and living conditions of the residents of the area have significantly improved.

Survey results suggest the following impacts:

i) The land prices prior to STP commissioning and after the commissioning in the past 20–30 years have increased 100–250 times. This trend has subsequently brought huge infrastructure growth in the area.
ii) Private hospitals and private universities have been established in the vicinity, meaning more employment opportunities and better urban services.
iii) The nuisances of odor and high potency wastewater have been eliminated, bringing more residential complexes in the area, which has enhanced social connectivity.
iv) No abnormal issues with waterborne diseases, diarrhea, or infant and child mortality have been reported in the area.
v) The treated wastewater is discharged in colonies for agriculture; this has led to beautification in terms of enhanced horticulture and also revenues from farming.
vi) There has been a tremendous increase in employment opportunities and better development in the whole area.

This has also been a win–win situation for JMC in such a way that additional revenues are generated by selling the biogas and electricity along with eliminating the key menace of wastewater. The Delawas STP is a success story, which is being showcased to visitors, technical staff, and research students across Jaipur.

5.9 Recommendations and Way Forward

Laws and policies need to be oriented and framed in such a way that municipal authorities are mandated to tackle the problem of pollution of water bodies and pay attention to their liability to set up STPs in cities and towns to prevent pollution (Araral and Wang 2013). This activity needs to be recognized as one of the most important indicators of the overall development of the state.

Considering the widening gap between sewage generation and treatment capacity, a thoughtful action plan is required to fill this. Emphasis should be given to prioritize development of 100% treatment capacity up to the secondary level of treatment.

Full cost recovery should be targeted for development of new STPs by having tariffs and cost for reuse of treated sewage and recycled water and incorporating waste-to-energy methods. The Delawas STP is an example of a self-sustaining plant. If that target appears to be too ambitious, governments and urban local bodies should ensure adequate budget provision for recurring costs such as running and maintenance of STPs to begin with.

Also, a clear policy for use of treated sewage and recycled water needed to be in place for the most economic utilization of this water for industry, irrigation, and for the environment and ecology—that is, maintenance of urban parklands and forests in non-urban settings. Groundwater recharge with treated wastewater using managed aquifer recharge may also be explored based on groundwater mapping and quality studies.

With increased hospital wastewater coming into STPs, new issues are emerging, such as antibiotic-resistant bacteria in treated sewage. Significantly large total coliform counts have been found in Delawas and other STPs in Jaipur. There is further need to analyze the effluent characteristics in detail. Based on the presence of antibiotic resistance, tertiary treatments like chlorination may also be included in the treatment units.

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6

Baseline Study on the Drinking Water Quality, Sanitation, and Hygiene Status of Selected Schools in Varanasi, India and the Consequent Impact on Gender Parity

Meenu Gautam, Abha Maurya, and Madhoolika Agrawal

6.1 Introduction

School plays a crucial role in the social, cognitive, and creative development of a child. It is an institution that not only provides education to children but also facilitates learning under the act of right to education (RTE), which has four components:

1. **Availability** of infrastructure (including buildings and sanitation-related facilities) and programs to raise awareness regarding our basic rights at educational institutes.
2. **Accessibility**
   - Accessibility of nondiscrimination: Irrespective of discrimination, education should be accessible to all, specifically vulnerable groups of society.
   - Physical accessibility: Education should be within safe, physical reach either by requiring attendance at a rationally convenient location or through the use of technology.
   - Economic accessibility: Education should be affordable so that it is easily accessible to all.
3. **Acceptability**: Quality of education, form and/or curricula, and pedagogy should be relevant, culturally appropriate, and acceptable.

4. **Adaptability**: Education patterns should be flexible and adaptable toward changing societies and communities. Moreover, education should be in accordance with a student's diverse social and cultural settings.

Besides RTE, children have the right to basic amenities such as access to clean surroundings, safe drinking water, functional school toilets, and basic information on hygiene (Majumder 2009). Safe drinking water as well as proper sanitation and hygiene facilities enable a school environment that safeguards children's dignity and health, which promotes their attendance. Children are the agents of change not only in their families but also in their communities and the nation. In addition, teachers play a catalytic role in bringing out positive change in the behavior of children as well as in shaping future generations. Merely providing required facilities does not necessarily produce the desired result; rather, it must include the inculcation of hygienic behavior directly related to children dropping out of school, specifically girls. Inappropriate access to water, sanitation, and hygiene (WASH) facilities is the prime cause of about 88% of all diseases across the world. Approximately 1.5 million children die of diarrhea all over the world each year due to improper sanitation and unhygienic status (Srivastava 2013). Chronic diarrhea severely affects their development related to the mind, body, and immune system. Thus, safe drinking water, sanitation, and hygiene are important ingredients for health as well as a good standard of living for every human being.

The concept of sanitation used to be limited to proper disposal of human excreta, but now has changed completely to include proper disposal of liquid and solid wastes, food hygiene, personal hygiene, domestic hygiene, and environmental hygiene. In a developing country such as India, children do not have complete access to appropriate sanitation facilities, especially those in government schools. Such schools cope with broken, dirty, unsafe, and even a lack of sanitation facilities which makes them more prone to be foci of disease transmission. Thus, sanitation in schools is very important because schools—after the family home—are important places of learning for children and are a central place in the community.

6.1.1 Sanitation and Hygiene in Schools: Case Studies

India is one of the largest countries of the world with a population of more than 1.2 billion (Government of India 2011). Compared to other countries, the sanitation challenges in India are serious. Only 48.4% of the population is using improved sanitation facilities. Although 89.9% have access to a drinking water facility, it is difficult to say if this large number corresponds to the population consuming safe drinking water

(Ministry of Health and Family Welfare 2016a). Inadequate use of WASH facilities and poor hygiene practices have increased the severity of the country's challenges, which plausibly have led to only 68.8% of the female population in the over 6 years age group ever having attended school (Ministry of Health and Family Welfare 2016a). India has made significant inputs through various policies, norms, and programs in order to raise primary school enrollment rates but was less successful in averting dropouts. According to the Ministry of Human Resource Development, the national dropout rate at the secondary level (17.9%) was significantly higher than at the primary level (4.3%) in 2014/15 (Jain 2017). Zafiu (2017) and Mukherjee (2010) stated that the reasons for the school dropout rates at an early age are

- inadequate educational infrastructure;
- poverty, inequality, social norms, and unpredictable employment scenario;
- inappropriate handwashing facilities and practices;
- lack of waste disposal arrangements in schools;
- health ailments due to poor drinking water and maintenance of available toilet facilities; and
- inadequate information on sanitation and hygiene among schoolchildren.

Research has shown that inappropriate sanitation and hygiene status is proportionally related to psychological stress (Hirve et al. 2015; Sahoo et al. 2015) and can increase women's vulnerabilities to WASH-related violence (House et al. 2014). Lack of appropriate facilities related to menstrual hygiene management may cause a girl's irregular attendance at school (Alam et al. 2017). Furthermore, a study conducted by Srivastava (2013) showed high dropout rates of girls from schools in India accredited to poor sanitation and hygiene facilities; only 34% of girls and 49% of boys complete school education.

According to the report by the Department of School Education and Literacy in India, the dropout rate of schoolchildren has declined from 5.6% in 2011/12 to 4.3% in 2013/14 with significant improvements in the number of schools, required facilities within the school campus, and percentage enrollment (Bhattacharya et al. 2016). At this level, the dropout rates for boys and girls have decreased by 1.36% (from 5.9% to 4.5%) and 1.2% (from 5.3% to 4.1%), respectively during the aforementioned period (Bhattacharya et al. 2016). Significant improvements in the dropout rate of schoolchildren have been observed in Jharkhand, Manipur, and Chhattisgarh, but the rates in West Bengal, Odisha,[1] Bihar,

[1] In 2011, the Government of India approved the name change of the Sate of Orissa to Odisha. This document reflects this change. However, when reference is made to policies that predate the name change, the formal name Orissa is retained.

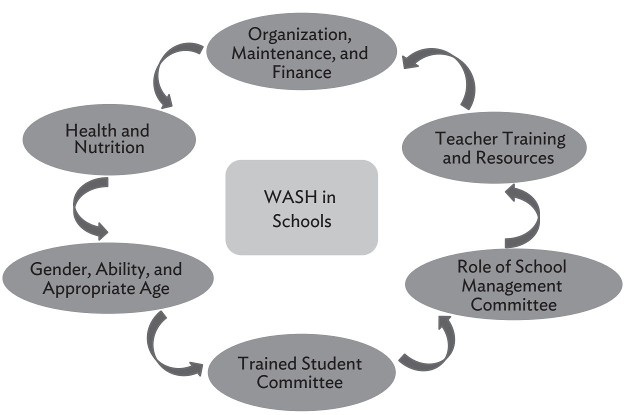
and Uttar Pradesh are still a cause of concern (UNICEF 2015). In Uttar Pradesh, 35% and 96.4% of the total population have access to improved sanitation and drinking water facilities, respectively (Ministry of Health and Family Welfare 2016b). Further, 63% of all women in the age group 6 years or above were found to have ever attended school (Ministry of Health and Family Welfare 2016b). To combat bad societal practices, childhood is the best time to inculcate good habits. Therefore, sanitation and hygiene education have been given a prime focus under the Total Sanitation Campaign (TSC) in every school throughout the country.

6.1.2 Campaigns to Sustain WASH Facilities in Schools

The provision of adequate WASH facilities in schools is synonymous with achieving the Sustainable Development Goals (SDGs), which encompass the following: (1) no poverty; (2) zero hunger; (3) good health and well-being; (4) quality education; (5) gender quality; (6) clean water and sanitation; (7) affordable and clean energy; (8) decent work and economic growth; (9) industry, innovation, and infrastructure; (10) reduced inequality; (11) sustainable cities and communities; (12) responsible consumption and production; (13) climate action; (14) life below water; (15) life on land; (16) peace, justice, and strong institutions; and (17) partnerships for the achievement of the goals.

Successfully achieving the SDGs requires proper planning, organization, maintenance, consistent monitoring, and fixed allocation of financial resources toward the aforementioned steps.

Figure 6.1: Sustainable Development Goals on Universal Education to Promote Gender Equality in Schools



Source: Authors.

India has initiated sustainable programs and campaigns such as Clean India: Clean Schools under the Swachh Bharat Mission to promote safe drinking water supply, sanitation, and hygiene education in schools. To ensure sustainability, such interventions need reinforcement to combat the high dropout of children from schools due to poor sanitation status. WASH interventions (provision of clean drinking water supply, enhanced facilities for excreta disposal, and the promotion of handwashing facilities) in schools are globally recognized as key tools to promote children's right to health and a clean environment, along with generational change in health promotion behavior and attitudes. The Government of India committed to scaling up the School Sanitation and Hygiene Education program by covering all government schools (both rural and urban) with WASH facilities by the fiscal year 2015/16 with a special focus on girls (Majra and Gur 2010). Unfortunately, the promises for school health and hygiene education programs and campaigns are not always fulfilled. Therefore, this study examined the ground realities as far as the school environment and sanitation status are concerned.

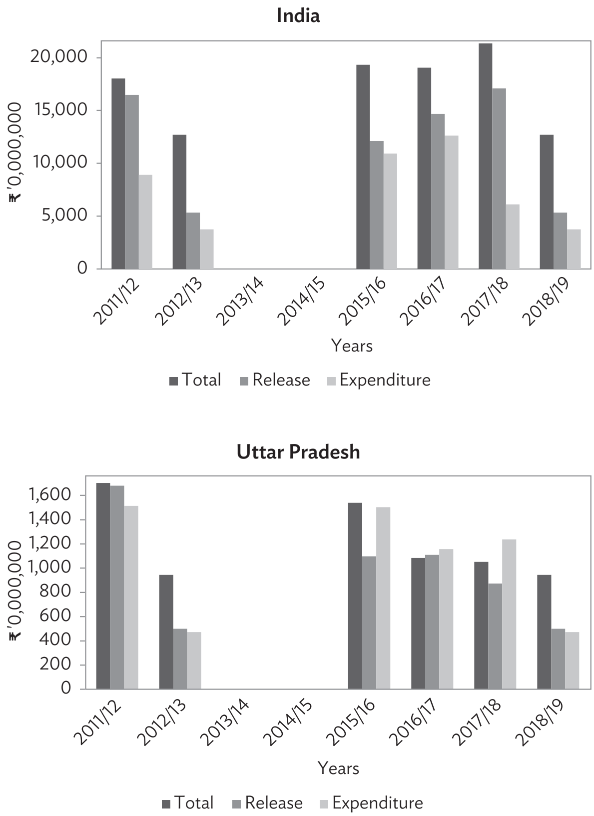
6.1.3 Policies to Sustain the Status of Sanitation in Schools

In India, children normally start their basic education at the age of 3–6 years. Basic education consists of five stages: primary, upper primary, middle, secondary, and senior secondary. Primary education in India is provided to children between 3 and 6 years of age, while children in the upper primary and middle educational stages are in the 5–12 years and 12–14 years age groups, respectively. Students at secondary (class 8–10) and senior secondary (class 11 and 12) levels spend 5 years in school. The net enrollment ratios at the primary and upper primary education levels in India were 87.3% and 74.7%, respectively, whereas the gross enrollment ratios at both stages were 99.2% and 92.8%, respectively (DISE 2016). In Uttar Pradesh, net and gross enrollment ratios at the primary stage were 83.07% and 60.5% and at the upper primary stage were 92.2% and 75.1%, respectively (DISE 2016).

The funding for compulsory education is jointly shouldered by the central, state, and local governments as well as by the students. For instance, the allocation of finances has increased in proportion (by 1%) since the previous year (2017/18) under the Union Budget for the financial year 2018/19. For education, ₹8,500 billion was allocated in India for the 2018/19 financial year. Figure 6.2 shows the allocation of funds to the country and the state (Uttar Pradesh) by the Ministry of Drinking Water and Sanitation toward the provision of safe drinking water supply and availability of facilities in maintaining sanitation and hygiene levels in schools in 2011/12 to 2017/18. However, no data have been collected for 2013/14 and 2014/15. The statistics of India show relatively less expenditure in maintaining sanitation and hygiene levels in schools, while in Uttar Pradesh the expenditures in 2015–2018 were higher than the total and released amount, which could be attributed to a greater reallocation in the field of sanitation and hygiene maintenance from other expenditure heads (Figure 6.2).

In India's decentralized fiscal system, compulsory education is supported and managed by the local government (Araral and Wu 2016). The central government is only responsible for strategy formulation and action planning at the national level. This has led to ignorance, insensitivity, and incapability (3Is) by government bodies, policy makers, and other stakeholders. Therefore, the allocation of public

Figure 6.2: Allocation of Budget toward the Facilitation and Maintenance of Sanitation, Hygiene, and Water Security in India and Uttar Pradesh



Source: Ministry of Drinking Water and Sanitation, Government of India, 2011–19 (http://data.gov.in).

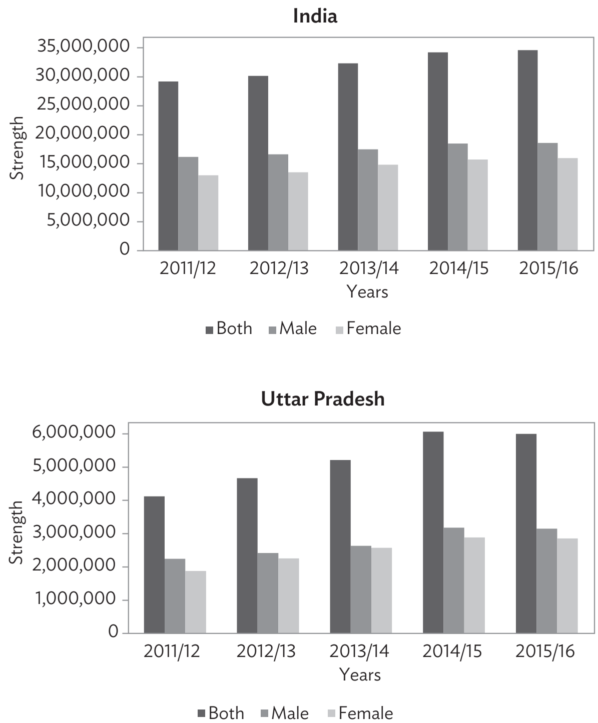
spending on education is relatively smaller for government schools and strongly in favor of private schools, which simply run on a self-finance structure. Due to their financial advantage, private schools have better facilities, which yield better educational quality and outcomes. Besides addressing the educational disparity between government and private schools, it is also essential for local governments to reduce education inequality between girls and boys through policies and reforms.

Policy implementation includes the 3As strategies—awareness, aspirations, and actions—undertaken by various parties and actors, including public participation. The extent to which policy goals can be achieved depends upon the success or failure of implementation. The consequences of policy implementation are also affected by the decisions and actions of other stakeholders (Yaro, Arshad, and Salleh 2017). Policy implementation in India is a challenging issue that needs to be tackled on a regular basis (Araral and Yu 2013). Thus, to achieve the policy goal, the following criteria should be addressed:

- Generate demand for sanitation facilities and accelerate sanitation coverage accomplished by awareness and health education.
- Encompass all the schools in the provision of sanitation facilities and encourage good hygiene behavior among students and teachers.
- Focus primarily on school girls with regard to the availability of sanitary facilities as well as a safe and secure environment to improve the gender parity index.
- Encourage cost-effective and appropriate technologies and applications to promote and upgrade sanitation facilitations in schools.
- Endeavor to lessen water- and sanitation-related diseases.

Under the influence of the TSC, emphasis is on the capacities of different stakeholders (nongovernment organizations, school teachers, masons, health workers, engineers, and district and block-level program managers) who play a significant role in improving the sanitation infrastructure, promoting girls' education, and providing social support for sanitation improvement. The Government of India relaunched the TSC as Nirmal Bharat Abhiyan in 2012 and Swachh Bharat Abhiyan in 2014 (Takkar et al. 2015) carrying out the core objectives as described earlier. The TSC's guidelines have undergone several modifications under the different relaunches to accomplish the goals. In 2004, the midterm review of the program spurred revision in the TSC guidelines with a focus on sanitary arrangements and construction of household toilets. Furthermore, the School Sanitation and Hygiene Education program component was strengthened, and provision of toilet facilities was extended to primary, upper primary, secondary, and senior secondary levels. In 2007, the TSC guidelines were modified to emphasize the Solid and Liquid Waste Management program in order to cover total sanitation in society (Takkar et al. 2015). With the onset of Clean India: Clean School Mission under Swachh Bharat Abhiyan, the country and the state (Uttar Pradesh) showed a progressive increase in the strength[2] of the schoolchildren from 2011/12 to 2015/16 (Figure 6.3). However, no such progressive improvement in the gender parity index has been observed in the past years (Figure 6.4).

Figure 6.3: Increase in the Strength of Boys, Girls, and Total Students in Schools of India and Uttar Pradesh in 5 Years

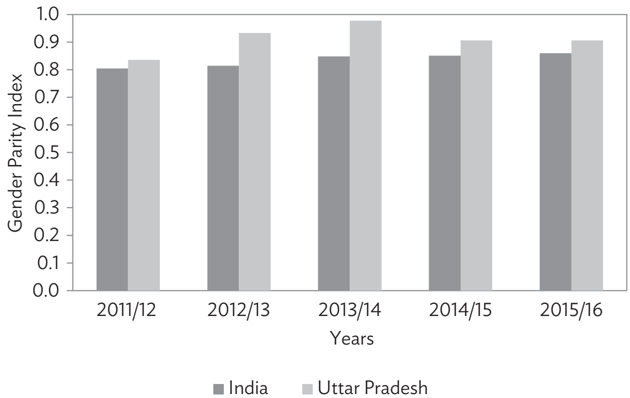


Note: Strength refers to the total number of students, teachers, and nonteaching staff.

Source: Ministry of Human Resource Development, Government of India, 2011–16 (https://mhrd.gov.in).

[2] Throughout this chapter, total strength refers to the total number of students, teachers, and nonteaching staff.

Figure 6.4: Variation in Gender Parity Index in 5 Years



Source: Ministry of Human Resource Development, Government of India, 2011–16 (https://mhrd.gov.in).

6.2 Rationale of the Study

6.2.1 Varanasi: The Target City

Varanasi is the fifth-most populated district in Uttar Pradesh with a population density of 2,395 people per square kilometer (Government of India 2011). The average literacy rate in Varanasi was 80.3%, with the male and female literacy 84.7% and 75.4%, respectively, and the gender ratio of the city was 886 women per 1,000 men (Census of India 2011). Varanasi was ranked 32nd in 2017, up from 418th in 2015, in performance benchmarking of districts. It falls in the average sanitation category including school sanitation status (Swachh Survekshan 2017). Thus, a case study was conducted in the city to assess the pupil–teacher ratio, availability of toilets and drinking water facilities, sanitation and hygiene status and their consequent impact on student enrollment, and gender parity in selected government and private schools of Varanasi. Such a study may help focus on the sanitation status in schools and available facilities to prompt the organizing committee, school authority, and local body to develop proper guidelines for sanitation facilities and service-level benchmarking of school sanitation with participatory and scientific approaches.

The study was carried out in Varanasi, which is situated in the Eastern Gangetic Plains of India, over 2 successive years (2015/16).

Prior to the current study, a baseline survey was conducted in 2010/11 on the status of sanitation and hygiene in selected government and private schools in Varanasi. The project was a joint venture with Banaras Hindu University, Varanasi Municipal Corporation, and the Deutsche Gesellschaft für Internationale Zusammenarbeit – Advisory Services for Environmental Management (GIZ-ASEM), funded by the German development cooperation at the ministerial level.

There were 14 schools selected randomly in the study area, including seven government and seven private schools. The schools dealt with all three levels of education—that is, primary, secondary, and senior secondary.

Secondary information relating to the study was provided by the Census of India (2011), DISE (2013), District Report Cards of Varanasi (2012/13), Annual Progress Report (2014/15), Education Section, Nagar Nigam, Varanasi, and administrators of the selected schools.

A questionnaire (Appendix 6) was prepared for the survey encapsulating the basic details about the schools, student enrollment, available teaching and nonteaching staff, basic amenities of the schools such as availability of drinking water supply, dustbins, access to clean toilet and other sanitary facilities (hand soap, toilet paper, bucket and/or mug, and clean towel). The sections were filled from interviews with teachers, nonteaching staff, principals, and students and from direct observations at the selected schools. Moreover, suggestions from staff and students regarding betterment of sanitation status and improved infrastructure of the school were also recorded.

The measurement of disparity between enrollment of girls and boys in a school is defined as the gender parity index (GPI) (Huebler 2008):

$$\text{GPI} = \frac{\text{Girls' enrollment in school}}{\text{Boys' enrollment in school}}$$

Gender parity is achieved if the GPI value equals unity. GPI values greater than 1 indicate disparity in favor of girls and vice versa.

The pupil–teacher ratio (PTR) is the ratio of the total number of students enrolled and total number of teaching staff in the school.

6.2.2 Sampling and Analyses of Drinking Water

Drinking water samples were collected in triplicate in 500 milliliter sterilized stoppered bottles from the selected schools (n=3). Prior to the collection of the water samples, drinking water point sources were sterilized using alcohol and a Bunsen burner to avoid any bacterial contamination. The pH of the sample was measured immediately after sampling and stored under cold conditions (4°C) for further assessment of their physiochemical and bacteriological parameters.

The water quality parameters such as pH, electrical conductivity (EC), and total dissolved solids (TDS) were analyzed immediately after the sampling using handheld devices such as a Milwaukee pH meter, Milwaukee conductivity tester, and Hanna TDS meter, respectively. Other parameters referring to total hardness, phosphate, chloride, and nitrate contents were analyzed in the laboratory following the standard methods (American Public Health Association 2005).

Bacteriological characteristics of drinking water samples were subjected to a presumptive coliform or most probable number (MPN) test using a multiple-tube fermentation method to enumerate total coliform count. Growth media (lauryl tryptose broth) and fermentation tubes were used, with serial dilution of water samples and inoculation thereafter into growth media. Samples were then incubated for 48 hours at 35°C to carry out the presumptive coliform test. Afterward, the positive tubes were transferred to brilliant green lactose bile broth (confirmation test) and incubated at 35°C for 48 hours. The presence of coliform was confirmed by the production of gas in the tubes (Nollet 2007).

The data were subjected to various statistical tests using the SPSS software, IBM SPSS Statistics 20.0. First, the descriptive analyses of range, mean, standard error, and percentage variation of generated data were done. The significance of differences among various parameters of drinking water samples collected from both government and private schools was verified by one-way ANOVA (analysis of variance) followed by post hoc Duncan's multiple range tests. Normality and homoscedasticity of data were tested using Kolmogorov-Smirnov's and Levene's tests, respectively, with distribution found to be normal ($p>0.05$) in all cases. The suitability of data for principal component analysis (PCA) was assessed by Kaiser–Meyer Olkin's (KMO) and Bartlett's tests. Thereafter, PCA was performed on different parameters of water from selected schools using a Varimax rotated factor matrix method. Pearson's correlation analysis was performed to investigate the relationship between total strength, total number of teaching/nonteaching staff, student enrollment, and access to available functioning toilets.

6.3 Limitations

The following limitations were identified:

- Unavailability of recent statistical data on the dropout rate of children from schools in Varanasi merely due to poor sanitation and hygiene conditions.
- Surveys in the schools related to perception from teachers, students, and principals were required to be completed in a limited time.
- Sometimes, the amount of information available is so large that gauging the exact figures is difficult.

6.4 Major Field Observations

Based on the survey, access to available facilities related to infrastructure was better in private schools as compared to government schools. Private schools provide top-notch facilities for overall development of children, and they charge high tuition fees for all this, which makes it difficult for low-income families to afford. They rely on student fees for any maintenance in the school. Private schools allocate a certain proportion of the financial structure to provide an environment that improves learning. Apart from education, they provide proper infrastructure, sanitary facilities, and equipment required for the physical development of children.

Government schools, on the other hand, either provide free education or impose a charge of ₹150–300 per 6 months up to class 9, whereas school fees for classes 10–12 are around ₹300–500 per 6 months so that lower sections of society can afford it. Government schools are financially aided either by funds or by the fee structure of schools, but schools were not getting as much attention as they required. School buildings were old and had not been whitewashed for a long time; toilets are few in number and not properly cleaned; electricity facilities were not appropriate; and sources of drinking water were hand pumps, jet pumps, or water supply from Jal Nigam. Some of the government schools were co-educational, but the schools surveyed did not have a single female teacher and were devoid of the essential facilities for girls. Sometimes, teachers and students of government schools contribute money themselves to fulfill the necessary requirements in their school. There were fewer people allotted in government schools for cleaning the toilets and campus. The premises of some of the government schools are also used for social activities such as marriage ceremonies and National Cadet Corps campaigning during holidays.

6.4.1 Total Number of Teaching and Nonteaching Staff and Students

School attendance has risen in India in recent decades, and this has been evidenced by the report of the National Survey Sample Office, which showed a steep rise in the enrollment of children from 1994 (68.4%) to 2005 (86.5%) (Datta, Dubey, and Simonsen 2018). This undoubtedly has been achieved by interventions of the Universalisation of Elementary Education (UEE) program under the District Primary Education Programme. The UEE program was gradually expanded and gave rise to Sarva Shiksha Abhiyan in 2000/01. Still, millions of children are far away from being enrolled in schools (UNESCO 2016). The results of the present study showed higher numbers of students as well as teaching and nonteaching staff in private schools compared to government schools (Table 6.1), which is primarily attributed to the available improved basic amenities, infrastructure, and secure environment (Yerande 2017). The numbers in private schools (total 6,811 and mean 973), including teaching staff (total 300 and mean 43), nonteaching staff (total, 69 and mean, 10), and enrollment of boys (total 3,920 and mean 560), were significantly higher ($p<0.05$) compared to government schools. On the contrary, the percentage enrollment of girls in government schools (total 2,829 and mean 404) was higher than in private schools (Figure 6.5).

Based on the average strength of girls and boys, the GPI in government and private schools was 0.76 and 0.64, respectively. Among three co-educational government schools, two of them showed a GPI value bigger than 1. Furthermore, more than 85% of private schools showed a GPI lower than 1. In government schools, the total number of students per teacher varied from 12 to 57 and in private schools from 8 to 67.

The dropout rates of children from both government and private schools in Varanasi in 2015/16 were found to be 18.4% and 11.6%, respectively. In addition, the dropout rates of boys (12.6% and 4.5%) and girls (13.3% and 7.7%) from government schools were relatively higher than from private schools (Figure 6.6). Although, the dropout rates for boys and girls have decreased by 1.36% and 1.2%, respectively, from 2011 to 2015, the status of children attending school among those enrolled is still a matter of serious concern (Bhattacharya et al. 2016). The causes for both girls' and boys' dropout of schools are poor economic conditions, low social status, burden of household work, lack of parental guidance in studies owing to low level of education of parents, large family size, failure in examination, lack of time for study, conservative societies, and even punishment by teachers (Kaul 2018). The low percentage enrollment of girls in schools or dropout of girls after joining school may be attributed to the gender-insensitive environment and issues related to inappropriate sanitation facilities dealing with menstrual hygiene (Alagusundaram,

Table 6.1: Total Number of Teaching/Nonteaching Staff, and Girls' and Boys' Enrollment in Government (G) and Private (P) Schools

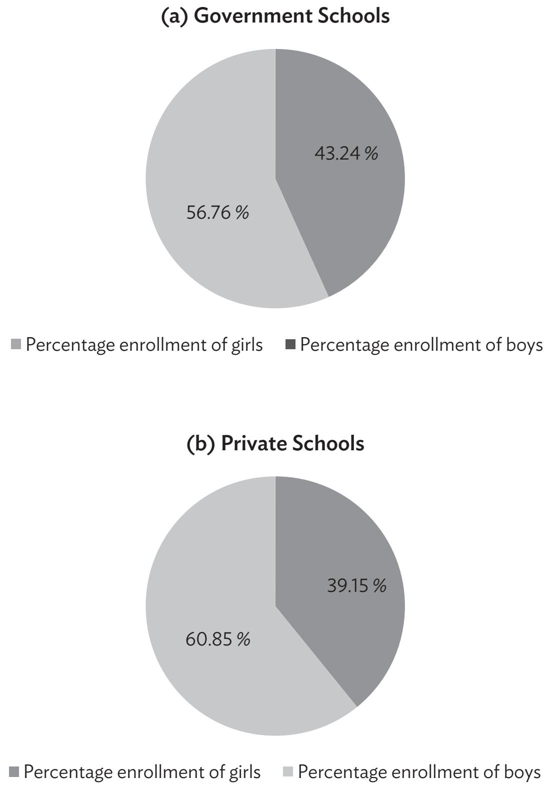
S. No.	Schools	Total Strength in School	Nonteaching Staff	Teaching Staff	Girls' Enrollment	Boys' Enrollment	Gender Parity Index	Students' Enrollment	Pupil–Teacher Ratio
	Government								
1	G1	2,084	11	73	0	2,000	NA	2,000	27
2	G2	2,666	10	46	2,610	0	NA	2,610	57
3	G3	112	4	8	100	0	NA	100	13
4	G4	213	2	11	40	160	0.3	200	18
5	G5	1,543	11	32	0	1,500	NA	1,500	47
6	G6	77	3	2	44	28	1.6	72	36
7	G7	67	2	5	35	25	1.4	60	12
	Private								
8	P1	1,247	11	36	500	700	0.7	1,200	33
9	P2	529	5	24	350	150	2.3	500	21
10	P3	1,204	7	55	350	792	0.4	1,142	21
11	P4	2,051	26	125	760	1,140	0.7	1,900	15
12	P5	846	11	35	200	600	0.3	800	23
13	P6	116	3	13	42	58	0.7	100	8
14	P7	818	6	12	320	480	0.7	800	67

NA = not applicable.

Note: Total strength refers to the total number of students, teachers, and nonteaching staff.

Source: Authors.

Figure 6.5: Percentage Enrollment of Girls and Boys in Government and Private Schools



Source: Authors.

Sivakumar, and Rajendraprasad 2016; Sahin, Arseven, and Kiliç 2016). These cumulative factors greatly affect girls' attendance, leading to poor performance and high dropouts, thereby decreasing their chances of completing their education. Several socioeconomic factors contribute to a pro-male bias, particularly in educational expenditure and gender discrimination by parents in expectations of old age support (Alderman and King 1998). However, gender inequalities in school enrollment have declined in recent decades in India (Psaki, McCarthy, and Mensch 2018). The population of girls (over 6 years of age) who ever attended school has increased from 58.3% to 68.8%, while the percentage of girls with 10 or more years of schooling has risen from 18.3% in 2005/06 to 32.9% in 2015/16 (Ministry of Health and Family Welfare 2016b).

Figure 6.6: Dropout Rate of Children from Government and Private Schools in Varanasi in 2015–2016
(%)

Source: Authors.

On average, the total numbers of students per teacher in government and private schools were 30 and 27, respectively (Table 6.1). The Right to Education (RTE) Act recommends a PTR of 30:1 for schools (Majumder 2009). The total number of students per teacher varied from 12 to 57 in government schools and from 8 to 67 in private schools. Thus, 57.1% government schools and 85.7% of private schools complied with the norm for the PTR. Even the best teacher struggles to teach a large number of students. The RTE places prime focus on building the capacity and agency of teachers to ensure quality education in schools. All at once, it should be ensured that the teachers are well educated and professionally trained to provide the best education to students.

6.4.2 Access to Drinking Water Supply

Access to a safe drinking water facility is every child's right (Majumder 2009). Many schools in developing and developed countries lack adequate water and sanitation services, with associated potential detrimental effects on health and school attendance (Haines, Rogers, and Dobson 2000). Populated places such as schools and residential areas should have a defined number of drinking water points with clean and safe water supply. Such places should be equipped with at least one drinking water point for every 250 people within a 400-meter radius as per the recommendation of the World Health Organization (WHO 2005). The presence of drinking water points in government and private schools varied from 1 to 12 and from 2 to 15, respectively (Table 6.2). On average, both types of schools contained six drinking water points within the campus. However, a wide variation in the total number of persons per drinking water point was found within government and private schools. In government schools, the total number of persons per drinking water point varied from 25 to 296; in private schools, it ranged from 58 to 301. The present study revealed that 78.6% of sampled schools followed the WHO norm, and in the rest there were more than 250 people per drinking water point. A total of 85.7% of government schools and 71.4% of private schools followed the WHO norm for the availability of drinking water points in schools. Moreover, drinking water point sources were hand pumps, jet pumps, *tullu* pumps, and taps. Approximately 14.3% of government schools had an aqua guard system at the drinking water points, while 71.4% of private schools had access to a drinking water supply through a water purifier (Table 6.2). In less than 50% of sampled schools, drinking water points were equipped with an aqua guard system, among them one government school and five private schools (Table 6.2).

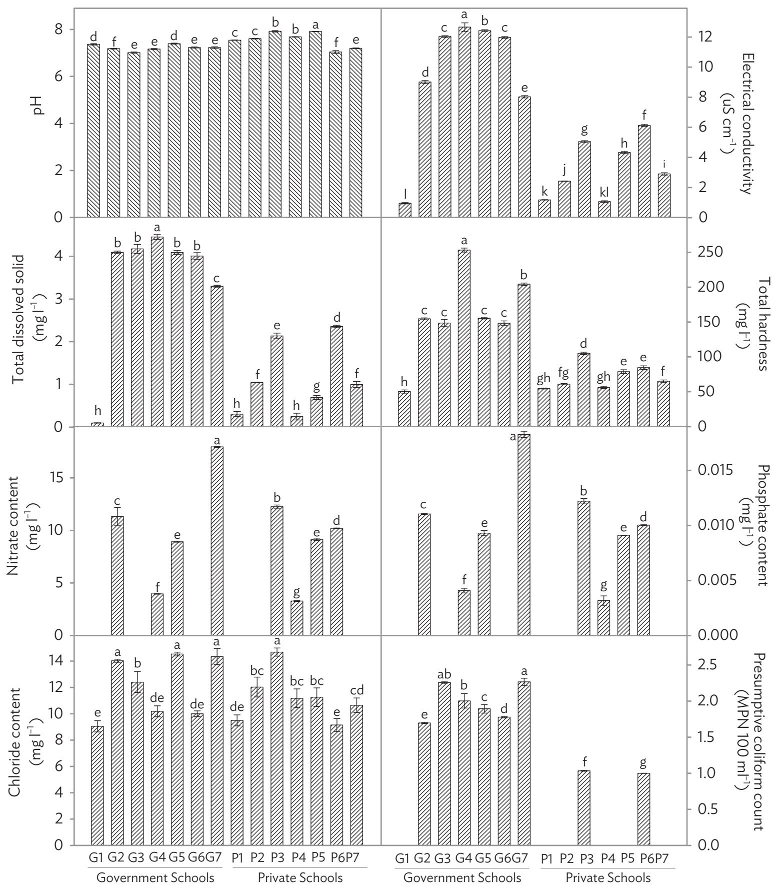
The quality of drinking water collected from selected government and private schools was assessed through physicochemical and bacteriological tests (Figure 6.7). Drinking water samples collected from different schools showed a significant variation ($F=139.08$, $p<0.01$) in pH, which ranged from 7 to 7.9. According to the WHO and the Indian Standard Institution (ISI), the recommended pH range is between 6.5 and 8.5 for good water quality (Chalchisa, Megersa, and Beyene 2018; Kumar and Puri 2012). Electrical conductivity (EC) determines the amount of substituents in water (Yilmaz and Koç 2014). Values recorded from schools ranged from 0.96 to 12.66 µS/cm (Figure 6.7), with EC values of drinking water samples collected from government schools significantly higher (F value=280.89, $p<0.01$) than from private schools. The EC value of water samples from government schools ranged from 0.96 to 12.66 µS/cm, while those from private schools ranged

Table 6.2: Total Number of Drinking Water Points, Number of Toilets, and Available Sanitary Facilities for Teaching/Nonteaching Staff, Girls, and Boys in Government (G) and Private (P) Schools

S. No.	Schools	Total Number of Drinking Water Points	Total Number of Persons per Drinking Water Point	Drinking Water Points with Aqua Guards	Total Number of Toilets in the School	Total Number of Toilets for Staff	Total Number of Toilets for Girls	Total Number of Toilets for Boys	Available Sanitary Napkins for Girls	Status of Available Sanitary Facilities in Toilets	Status of Cleanliness
	Government										
1	G1	12	173	Yes	60	3	0	57	NA	Fair	Good
2	G2	9	296	No	10	2	8	0	No	Very poor	Very poor
3	G3	6	19	No	4	0	4	0	Yes	Poor	Fair
4	G4	2	106	No	8	0	4	4	No	Very poor	Very poor
5	G5	8	198	No	12	4	0	8	NA	Very poor	Poor
6	G6	3	25	No	2	0	1	1	NA	Fair	Fair
7	G7	1	67	No	2	0	1	1	NA	Good	Good
	Private										
8	P1	15	83	Yes	29	4	10	15	Yes	Good	Good
9	P2	2	268	Yes	9	0	6	3	Yes	Good	Fair
10	P3	4	301	No	12	0	3	9	No	Good	Poor
11	P4	7	179	Yes	32	4	12	16	Yes	Very good	Good
12	P5	4	211	Yes	18	2	4	12	NA	Good	Good
13	P6	2	58	No	8	0	2	6	No	Poor	Fair
14	P7	5	163	Yes	12	4	4	4	Yes	Good	Good

NA = not applicable.
Source: Authors.

Figure 6.7: Physicochemical Properties and Presumptive Coliform Count in Drinking Water Samples Collected from Government (G) and Private (P) Schools in Varanasi



Source: Authors.

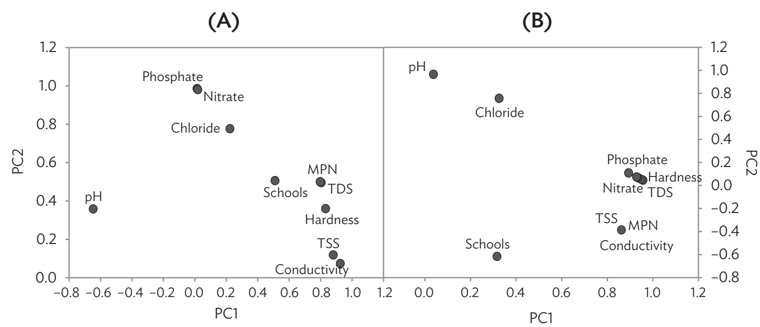
between 1.12 to 6.12 μS/cm. The EC values of drinking water samples from government and private schools stood at an average of 9.58 and 3.29 μS/cm, respectively, which was far below the EC value (11.08 μS/cm) recorded by Oyem, Oyem, and Ezeweali (2014) in groundwater samples collected from Agbor and Owa towns of Nigeria. The TDS value in drinking water samples from government schools (0.10–4.50 mg/l) was significantly (F value=110.11, $p<0.01$) higher compared to private schools (0.25–2.36 mg/l), but its value in drinking water samples collected from both school types was far below WHO- and ISI-recommended guidelines of 1000 and 2000 mg/l, respectively (Figure 6.7). Water with TDS values lower than the prescribed levels is suitable for both drinking and irrigation purposes (Shahidullah et al. 2000).

Total hardness of drinking water samples collected from government schools was significantly higher (F value=708.39, $p<0.05$) compared to private schools. Total hardness of water samples from government schools was in the range of 50.37–253.08 mg/l and 54.68–105.19 mg/l in the case of private schools. Similarly, chloride content in water samples from selected schools showed significant variation (F value=15.37, $p<0.05$) between 9.04 and 14.69 mg/l (Figure 6.7). However, total hardness and chloride content in drinking water were within WHO (500 and 200 mg/l, respectively) and ISI (300 and 250 mg/l, respectively) safe limits for drinking water. No nitrate and phosphate contents were detected in each of the three government (G1, G3, and G6) and private (P1, P2, and P7) schools. Nitrate content in drinking water samples from government and private schools ranged between 0–17.95 and 0–12.26 mg/l, respectively. Phosphate content was in the 0–0.02 mg/l range in water samples from government schools and the 0–0.012 mg/l range in water samples from private schools. The contents of nitrate and phosphate were higher than the prescribed limits as per WHO norm (0 mg/l) but were within ISI limits (nitrate, 45 mg/l and phosphate, 0.10 mg/l) for drinking water.

The presumptive coliform count in drinking water samples collected from government schools were within 0–3; among the private schools, P3 and P6 showed a coliform count within 1–3 (Figure 6.7). Results of ANOVA showed significant variation (F value = 11.55, $p<0.05$) in observed coliform count in drinking water samples collected from selected schools. Significantly higher coliform count was observed in water samples collected from government schools compared to private schools. Coliform count in drinking water from government schools and private schools ranged between 0–2 and 0–1, respectively. When the presumptive coliform count per 100 milliliter of water is 0, it falls in the class I (excellent) category, class II (satisfactory) when it is 1–3, class III (suspicious) when it is 4–10, and class IV (unsatisfactory) when it is >10 (Kadri et al. 2018). Thus, more than half the private schools had *excellent* drinking water supply with the aqua guard system at water points. Furthermore, six government (G2, G3, G4, G5, G6, and G7) and two private (P3 and P6) schools supplied drinking water quality of *satisfactory* level. Drinking water point sources near toilet facilities or waste dumping sites may also be responsible for *suspicious* quality water. Therefore, drinking water points should be located far from such places. Moreover, drinking water points should not be used for handwashing after the use of toilets.

A PCA was performed to assess the relationship between different physicochemical and biological parameters of water samples collected from both government and private schools (Figure 6.8). In the former case, two principal components (PCs) were obtained, with PC1 contributing 56.3% of total variance (Eigenvalue=5.63) with strong positive loadings (>0.70) for selected government schools, bacterial coliform, TDS, hardness, and EC. PC2 explained 22.5% of total variance (Eigenvalue=2.25) with positive loadings for chloride, phosphate, and nitrate. Furthermore, the PCA of selected parameters of drinking water samples from private schools showed that PC1 and PC2 contributed 67.87% (Eigenvalue=6.18) and 22.4% (Eigenvalue=2.24) of total variance, respectively. PC1 showed high loadings for TDS, hardness, conductivity, nitrate, phosphate, and bacterial coliform, while PC2 showed high loadings for pH and chloride contents in water.

Figure 6.8: Principal Component Analysis for the Relationship between Selected Physicochemical and Biological Properties of Drinking Water Samples Collected from (A) Government and (B) Private Schools



Source: Authors.

6.4.3 Access to Toilets and Other Sanitary Facilities

Access to basic amenities in India was very poor with almost 90% of the schools having no toilet facilities. Attention to hygiene was brought into focus in the early 2000s after the launch of the Sarva Shiksha Abhiyan program (Kingdon 2007). In the present study, the total number of toilets in government and private schools varied in the 2–60 and 8–32 range, respectively. Approximately 42.9% of government schools and 57.1% of private schools have access to separate toilets for teaching and nonteaching staff (Table 6.2). However, there is no norm for total strength-to-toilet ratio in school campuses. Per the WHO (2009), the standard girls-to-toilet and boys-to-toilet ratios are 25 and 30, respectively (Table 6.2). In government schools, there were 10–326 girls and 25–188 boys per toilet. Moreover, there were 21–117 girls and 10–120 boys per toilet in private schools. Thus, approximately 40% of government schools followed the WHO norm for the toilet ratios (Table 6.2). Most strikingly, only 14% of private schools followed the standard WHO student-to-toilet ratio for girls and boys. This could be attributed to higher student numbers in private schools and lower allocation of resources toward provision of proper sanitation facilities.

The availability of sanitary facilities such as sanitary napkins for girls, hand soap, toilet paper, buckets, mugs, and dustbins were assessed on the day of the visit to the government and private schools. In around 33% of government schools and 66% private schools, girls were provided with sanitary napkins during their menstrual period. Access to sanitary facilities (handwashing facilities, buckets, mugs, toilet paper, disposal bins, and clean towels) within a toilet room and status of cleanliness were fair to very good in private schools. In addition, more than 50% of government schools showed poor access to sanitary facilities in toilets, whereas 28.6% had fair access to sanitary facilities (Table 6.2). Nearly 85.7% of private schools provided hand soap, toilet paper, buckets, mugs, and dustbins within a toilet cubical. The private schools were cleaned twice or thrice a day. On the contrary, access to sanitary facilities and status of cleanliness of toilets were found in very poor to good condition, which could be attributed to the improper care of toilet and associated facilities. Government schools (42.7%) were not properly cleaned, although 28.6% were fairly clean and the rest were found cleaned on the day of visit. The majority of private school toilets (85.7%) were cleaned, though the rest were stained and smelly.

The Pearson's correlation test exhibited a strong and positive correlation between total strength of schools and total number of toilets in the school campus (0.062, $p<0.05$). Similarly, the total number of teaching and nonteaching staff and available toilets (0.563, $p<0.05$) showed a positive correlation. Furthermore, strong positive correlations existed between girls' and boys' enrollment with the availability of respective toilets within the campus (0.056, $p<0.05$ and 0.822, $p<0.05$, respectively) (Table 6.3). Access to clean and appropriate number of sex-specific school toilets plays an important role in raising student enrollment, especially girls, and reducing their dropout rates. Results from the present study agree that the absence or availability of fewer toilets in schools exposes pubescent girls to regular danger of verbal

Table 6.3: Correlation Coefficient between Total Strength, Teaching/Nonteaching Staff, Girls' and Boys' Enrollment in School, and Total Number of Accessible Toilets (n=14)

	Total school strength	Total number of toilets in campus	Total number of staff	Total number of toilets for staff	Girls' enrollment	Total number of toilets for girls	Boys' enrollment	Total number of toilets for boys
Total school strength	1	0.621*	0.770*	0.667*	0.661*	0.398 ns	0.607*	0.479 ns
Total number of toilets in campus		1	0.690*	0.590*	–0.017ns	0.153 ns	0.825**	0.955**
Total number of staff			1	0.563*	0.314 ns	0.539*	0.652*	0.531 ns
Total number of toilets for staff				1	0.196 ns	0.358 ns	0.666*	0.414 ns
Girls' enrollment					1	0.569*	–0.196 ns	–0.186 ns
Total number of toilets for girls						1	–0.103 ns	–0.132 ns
Boys' enrollment							1	0.822*
Total number of toilets for boys								1

*p<0.05, **p<0.01, ***p<0.001, ns: insignificant, staff includes teaching and nonteaching.

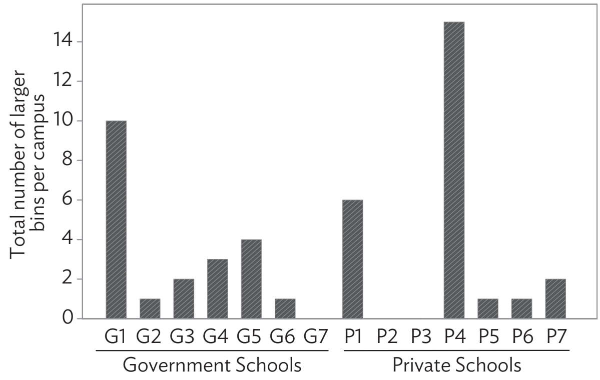
Note: Total strength refers to the total number of students, teachers, and nonteaching staff.

Source: Authors.

and physical harassment, which can lead to low female educational achievement. Although menstruation lasts only a few days each month, girls at the beginning of puberty undergo certain physical and emotional changes on a regular basis and are normally unwilling to use public toilets due to privacy concerns and harassment (UNICEF 2005; Leach et al. 2003). Adukia (2017) reported that unisex toilets are also inadequate for pubescent girls. Therefore, separate sex-specific toilets are a prerequisite in view of privacy and safety of students. Girls and boys alike are also often victims of bullying and teasing in toilets (Malhi, Bharti, and Sidhu 2014). Thus, inadequate school sanitation worldwide appears to hinder educational attainment, and gender-specific school toilets have the potential to improve gender parity in education for children in puberty.

Improper or unsafe disposal of waste is a major cause of several vector-borne diseases, which variably or invariably may lead children to drop out of school due to ill health (Soliman et al. 2017; UNICEF 2011). Wherever waste is thrown out, it should be collected in a dustbin and disposed in a proper dumping site to make the environment clean and healthy. Based on the study survey, 21.4% of schools did not have access to larger dustbins. At least one large dustbin was found in within the campus in 85.7% of government and 71.4% of private schools (Figure 6.9). There should be at least one smaller bin in classrooms, offices, and toilets, and one larger bin within the school campus.

Figure 6.9: Total Number of Larger Dustbins within the School Campuses of Government (G) and Private (P) Schools

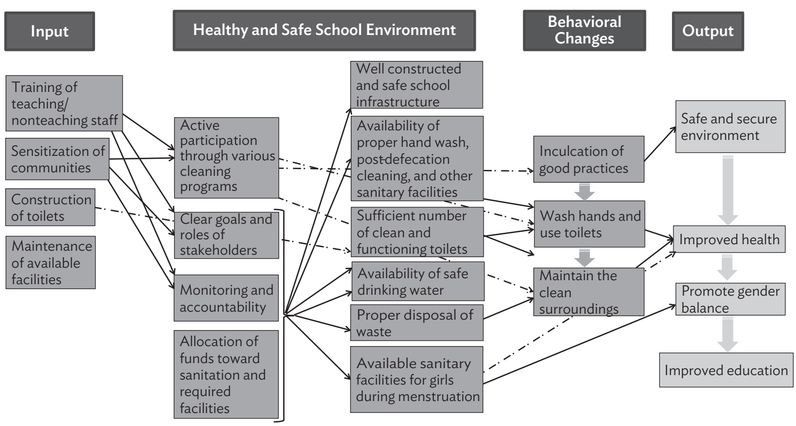


Source: Authors.

6.5 Implementation to Improve Sanitation and Hygiene in Schools

Execution of effective policies is essential at national, state, district, and school levels to encourage and facilitate the achievement of WASH and the SDGs, thereby promoting gender balance in schools. A supportive policy environment should allow stakeholders at all the levels to establish effective governance and management systems in order to plan, fund, implement, and coordinate improvements (Araral and Wang 2013). The essential steps at the district and local (community and school) levels are presented in Figure 6.10.

Figure 6.10: Probable Inputs to Bring About Behavior Changes in Schoolchildren, Teaching, and Nonteaching Staff to Improve Education and Health, and to Promote Gender Balance



Source: Authors.

6.5.1 District Level

- Provide appropriate training and information to teaching and nonteaching staff.
- Raise awareness regarding WASH, SDGs, and School Sanitation and Hygiene Education in schools among key stakeholders.
- Allocate funds for the management of entire infrastructure in a planned way and for new developments.

- Include appropriate plans and specialists for new structures and improvements to prevailing structures.
- Ensure that the national regulatory framework is amended with appropriate guidelines and support for compliance at the district level.
- Consistently monitor all the ongoing conditions in schools, preferably government schools, and promote remedial actions wherever required.

6.5.2 School Level

- Assemble support from local stakeholders, teaching and nonteaching staff, children, and families to sustain a healthy environment.
- Allocate funds for planned improvements and new developments.
- Delineate a set of targets, policies, and procedures for the implementation of national standards and/or guidelines in a way which reflects local conditions.
- Formulate appropriate bodies to oversee the aforementioned enactments in the school.
- Evaluate existing conditions by consulting with local stakeholders (including staff and local community), monitor ongoing conditions, and take remedial actions wherever required.
- Provide required advice and training to staff, schoolchildren, and parents to achieve the set of goals.

Management of various interdependent aspects of WASH at the local level requires effective coordination of community, government, and national authority representatives, along with schoolchildren, teaching and nonteaching staff, and parents. This will help create strong links with the local department of environmental health and official meetings on a regular basis. The flowchart (Figure 6.10) shows a simple method and inputs at different levels to fill the gaps and promote achievable and suitable improvements following the specific conditions of schools, specifically government schools.

6.5.3 Inputs

Several activities are required to create and maintain a healthy school environment, routinely by teaching and nonteaching staff, schoolchildren, parents, and local authorities (Figure 6.10). A training and management program could foster awareness regarding the importance of their role in developing, maintaining, and promoting a healthy school environment. In addition, the importance of sanitation and hygiene education should be taught as part of the curriculum in every school. All these inputs cumulatively encourage the active participation of school groups and other stakeholders in cleaning programs. This may further help stakeholders to come up with clear goals and roles in resolving the existing problems, facilitating the requirements, and maintaining the existing facilities in schools.

6.5.4 Healthy and Safe School Environment

Of foremost importance is the provision of required facilities related to safe water supply and sanitation, and their regular maintenance should be accentuated in the course of design and construction (Figure 6.10). Also, budget needs to be available from the beginning of a program so that facilities are hard-wearing, durable, and also possible to maintain even without specialist skills and/or equipment. The local health department should be a major partner for the service-level benchmarking so that in the case of uncertain institutional funding there is some form of local income-generating system in place. A monitoring system should use a set of indicators, such as the following, to identify problems and correct them:

1. Classrooms should be frequently cleaned.
2. Functioning drinking water points should be accessible in schools at all times.
3. Schools should be equipped with adequate quantity of water for drinking and personal hygiene (Table 6.4).
4. Toilets should be aided with functioning water points, flushing systems, proper door latches, soap, clean towels, buckets or mugs, and dustbins within the school premises.
5. There should be a sufficient number of functioning toilets (one toilet per 25 girls or female staff and one toilet plus urinal per 30 boys or male staff) (WHO 2009).
6. Toilets must be easily accessible (not more than 30 meters from all users).
7. Toilets should be hygienic to use, easy to clean, and provided with privacy and security.
8. Solid waste should be collected from the school campus daily and disposed of safely.
9. Wastewater must be disposed of quickly and safely.
10. Many girls during menstruation were reported being absent from school due to lack of disposal systems, broken locks or doors of toilets, lack of water taps, missing buckets, and poor

Table 6.4: Quantity of Water Required for Different Purposes in Schools

Purposes	Quantity of Water Required (liters per person per day)
Drinking water for all schoolchildren and staff	5
Nonresidential schoolchildren and staff	5
Conventional flushing toilets	10–20
Pour-flush toilets	1.5–3
Anal washing	1–2

Note: Staff includes teaching and nonteaching staff.
Source: Adams et al. (2009).

water supply. Fear of being in their menstrual phase during an indefinite time also adds to the dropout of girls from schools. Thus, distribution of menstrual products should be free, and there should be proper availability of sanitary facilities in schools and educational institutes.

6.5.5 Hygiene Behavior

Children are able to learn and quickly adapt their hygiene behavior, specifically in their home and schools (Figure 6.10). Since they spend a significant time in school, the school environment should be clean and healthy, and teachers play a significant role in bringing out the behavior change through education and practical implications. More broadly, health should be promoted in all aspects of the school environment and activities. Facilities and resources enable the staff and schoolchildren to bring about behavior changes that control disease transmission in an easy and timely way. These not only facilitate the inculcation of good practices in their day-to-day life, but also encourage and motivate them to keep their surrounding environment clean and hygienic.

6.5.6 Outputs

At present, many schools (mainly government schools) are far from achieving the prescribed levels of WASH. They do not have suitable facilities, resources, skills, or adequate institutional support. Therefore, suitable steps should be taken to prioritize necessary improvements and to work in the direction of identifying problems, targeting them immediately, and resolving them in a timely manner to lead to an increase in GPI (Figure 6.10).

6.6 Conclusions

This study shows that the total strength in private schools including teaching and nonteaching staff and enrollment of boys were higher compared to government schools, while enrollment of girls was higher in government schools of Varanasi. GPI was higher in government schools than in private schools, as was the average number of students per teacher. Both government and private schools followed the RTE norm for the availability of drinking water points in a campus. However, only 14.3% of government schools and 71.4% of private schools had an aqua guard system at drinking water points. All the selected physicochemical properties of drinking water samples were within the prescribed WHO and Indian standards except nitrate, phosphate, and chloride, whose contents in the water samples were above WHO safe limits. Based on presumptive coliform counts, drinking water samples from government schools were satisfactory, while most private schools had excellent quality of drinking water. Access to proper sanitary facilities, specifically for girls, and clean toilets were relatively good in private schools. Despite several norms, policies, and reforms, there is a wide gap between the status of sanitation, availability of basic amenities, and drinking water quality in government and private schools, which has prompted gender disparity in schools. Thus, to close up the differences between the school types, a clear set of goals should be encapsulated with proper monitoring, maintenance, management, and service-level benchmarking of school sanitation and hygiene with the right to availability, accessibility, acceptability, and adaptability. In addition, central focus should be given to girls regarding availability of sanitary facilities as well as a safe and secure school environment in order to combat their dropout rates.

6.7 Recommendations

Based on the survey as well as evaluation of drinking water quality along with sanitation status in selected government and private schools, the present study suggests the following:

- A participatory assessment of various issues of sanitation involving students, teachers, parents, and committee members.
- Maintenance of all the existing facilities provided to schools at regular time intervals by the school authority.
- Increase in allocation of financial resources toward improved drinking water supply to improve sanitation levels and access to proper sanitary facilities.

- Teaching methods should include small group activities focusing on the benefits of improved sanitation and seriousness of diseases that may result from poor sanitation status as well as lack of any relevant knowledge. This strategy would inculcate hygienic behavior in children and encourage them to keep their surrounding environment clean.

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Appendix 6: Questionnaire Details

Details About Schools

- Name of the school
- Type of the school
  - Government
  - Private
- Total number of teaching and nonteaching staff
- Total number of teaching staff:
  - Male teacher
  - Female teacher
- Total number of students enrolled:
  - Boys
  - Girls

Access to Drinking Water Supply

- Total number of functional drinking water points
- Sources of drinking water supply
  - Groundwater
  - Jal Nigam
- Drinking water points equipped with aqua guard system
  - Yes
  - No
- Is drinking water storage area clean?
  - Yes
  - No
- Is drinking water storage area far away from toilets?
  - Yes
  - No
- Is same tap water is used for drinking purpose and handwashing after toilet?
  - Yes
  - No

Access to Toilet and Sanitary Facilities

- Does the school have toilets
  - If yes (How many?)
  - If no (Where do students and staff go for toilet?)
- Total number of functioning toilets in school campus
- Are there separate toilets for girls and boys?
  - Total number of toilets for girls?
  - Total number of toilets for boys?

- Are there separate toilets for teaching and nonteaching staff?
  - If yes (How many?)
- Are the toilets get cleaned?
  - Daily (once/twice/thrice)
  - Weakly
  - Monthly
  - Not cleaned
- Are toilets provided with proper sanitary facilities?
  - Handwashing facilities
  - Toilet paper
  - Bucket/mug
  - Clean towel
- Availability of sanitary napkins for girls
- Are toilets provided with proper latch in door?
  - Yes
  - No
- Is surrounding area of toilets clean?
  - Yes
  - No

Waste Disposal

- Does the school has any larger dustbin (excluding those that are in classroom/office/toilet)
  - Yes (How many?)
  - No

Table A6.1: Survey of Perceptions from Teachers and Students of the School with Respect to Sanitation Status and Their Suggestions

Category	Toilet cleanliness	Available sanitary facilities	Available sanitary napkins for girls	Cleanliness of campus	Suggestions (if any)
Teaching staff					
Nonteaching staff					
Boys					
Girls					

7

Water Supply and Sanitation: PPP "Good Practices" from India

Tamanna M. Shah

7.1 Introduction

Philip Ball, author of the book *Life's Matrix: A Biography of Water*, emphasizes the importance of liquid water to maintain the delicate chemistry that makes life possible. Water is the molecule of life. It is the backbone of all life activity and the most precious resource of planet Earth. Safe drinking water and improved sanitation has many benefits, including work opportunities and improved health for women, children, and families across the world. But there is also a shortage of this resource and water scarcity is now a global issue and threat. Around three in 10 people worldwide, or 2.1 billion, lack access to safe, readily available water at home, and six in 10, or 4.5 billion, lack safely managed sanitation (WHO and UNICEF 2017).

Water is related to every aspect of our life. The 2030 United Nations Agenda for Sustainable Development recognizes the importance of proper management of safe drinking water, effective sanitation, and good hygiene as an end in itself and also as a driver of progress for many of the Sustainable Development Goals. Water-related problems are particularly acute in Asia. Asia faces water insecurity, with, "less freshwater - 3,920 cubic meters per person per year - than any continent other than Antarctica. Almost two-thirds of global population growth is occurring in Asia, where the population is expected to increase by nearly 500 million people within the next 10 years. Asia's rural population will remain almost the same between now and 2025, but the urban population is likely to increase by a staggering 60%" (Asia Society 2009, 9).

In recent years, the Asia and Pacific region has seen unprecedented development. It is now an epicenter of economic and population growth. However, there is growing water insecurity because of the increased demand on its finite resources. Given that the region supports the livelihoods for nearly 1.7 billion people, "a lack of access is a silent crisis that has claimed more casualties through illness than any conflict" (WWAP 2015). The World Water Council (WWC 2017) reports that the region is, "home to nearly two-thirds of global population but only uses one-third of the world's water resources" (n. p.). But there is a serious threat to this resource through issues such as deteriorating quality, and increased exposure to climate change and water-related disasters. The region is, "the global hot spot for water insecurity" (ADB 2016, 9), with per capita water availability being the lowest in the world. The report observes that countries like Afghanistan, the People's Republic of China, India, Pakistan, and Singapore are projected to have the lowest per capita water availability by 2050.

This chapter will demonstrate how ignorance, insensitivity, and incapability, or the "three I's", perpetuate water insecurity.

7.1.1 India's Water and Sanitation Challenge

In India, equal access to essential health, clean water, and sanitation services continues to be a priority. Due to its growing population, the country faces significant challenges in water provision, sanitation, solid waste management, and drainage (Araral and Ratra 2016). These resources are not equally distributed to all the people in the country; according to the 2011 census, 63.4 million people in the rural areas are living without access to clean water. Linked to the lack of equitable distribution of essential resources is the problem of extreme weather conditions and climate change. Additionally, 44% of the population continues to defecate in the open (Stewart 2017).

Over the years, the country has made remarkable strides in the eradication of polio and the elimination of neonatal tetanus. "Life expectancy at birth has doubled since independence, from 33 years in 1947 to 68 years in 2011" (Shastri & Bhatt 2018, 43). There has also been an improvement in some of the key health indicators like infant and maternal mortality rates, and the incidence of HIV, tuberculosis, and malaria. A reduction in these has helped India meet the UN Millennium Development Goals on health (MDGs 4, 5, and 6). Subsequently, in 2012, India launched the Nirmal Bharat Abhiyan Clean India Campaign. This campaign was adapted from the National Total Sanitation Campaign (1999–2012), the world's largest sanitation intervention. Nirmal Bharat

Abhiyan includes those elements that have been recognized as key for a successful approach to rural sanitation: a robust supply side providing access to hardware, intense promotion and demand creation, and a strong enabling environment.

Further, since the launch of the Government of India's flagship Swachh Bharat Abhiyan (Clean India Mission) scheme, over 50.17 million toilets have been built. National sanitation coverage in rural India has also crossed 70%, a record high, with more than 12 million toilets built.

Despite growing investment, rural sanitation grew at just 1% annually throughout the 1990s and only 22% of rural households had access to a toilet (Ministry of Drinking Water and Sanitation 2012). The system continues to be plagued with low budgetary allocations for health, which is only around 1% of GDP over the past decade (Kurian 2015). There is also a need to use these funds more efficiently and in a focused manner. The private sector, on the other hand, provides care to about 70% of the population and is unregulated and poorly integrated into health service delivery systems. According to ADB (2016), most of the problems that Asia today faces are not just related to the shortage of water, but rather are a result of poor water governance (Araral and Yu 2013).

7.1.2 Institutional Arrangement and the Role of the Central Government

The governance of urban water supply and sanitation (WSS) in India is divided between the central and state governments. The central government oversees the regulation and development of interstate rivers and river basins and establishes the policy framework for the management of water resources.

The Ministry of Urban Development (MoUD) is the principal coordinator of urban WSS sector activities; the Central Public Health and Environmental Engineering Organization is its technical arm. The MoUD receives assistance from the Ministry of Health and Family Welfare, Ministry of Water Resources (MoWR), the Ministry of Environment and Forests, and the Planning Commission (Table 7.1). MoWR has some responsibility in the regulation of ground water, but no agency currently plays the role of economic regulator of the urban WSS sector.

All matters concerning the urban WSS sector are within the domain of state governments. They are responsible for the proper allocation of water resources and also for establishing institutional systems for their development and management.

Table 7.1: Central Government Institutional Structure

Ministry	Institution	Responsibility
Planning Commission	Planning Commission	Planning and allocation of central government funds through Five-Year Plans
Ministry of Water Resources	Central Water Commission	Central policy making
	Central Ground Water Board	Regulatory activities of ground water concerning quality and overexploitation
Ministry of Environment and Forests	National River Conservation Directorate	Responsible for river bodies
	Central Pollution Control Board	Pollution watch
Ministry of Urban Development	Central Public Health Environmental Organization	Standards setting and harmonization between states
Ministry of Health and Family Welfare	National Institute of Communicable Diseases	Research and advocacy, particularly with civil society
Others	Housing and Urban Development Corporation	Funding housing and other infrastructure sectors
	Life Insurance Corporation	Development funding

Source: Locussol et al. (2006).

7.1.3 Public–Private Partnerships Interventions and Best Practices

In India, public–private partnerships (PPP) in water projects started in the mid-1990s. According to the Water and Sanitation Program (WSP) (2011), these projects focused on effectively managing the bulk water supply systems in the cities. However, these projects failed because of issues related to tariffs and lack of political support (ADB 2011). Today, around 60% of the PPP projects address concerns related to operations and maintenance (O&M), with little investment from the private sector (less than 10% of the total project costs in some cases), while the rest aim at sole bulk water augmentation and integrated water projects with both augmentation and O&M improvements (WSP 2011). To make the PPPs a success, an integrated approach needs to be adopted. An enabling environment should be created that focuses on effective project design and improves the long-term viability of the PPPs. Resources need to be managed efficiently and in a sustainable manner.

PPPs are promoted as a potential delivery mode for infrastructure services in a variety of sectors (Mahalingam and Seddon 2012). With a paucity of required finances, competencies, and capacities to meet the resource demands, state governments experiment with PPPs in water and sewerage services. Despite this being controversial (Estache and Fay 2007), it has been seen that well-designed and properly implemented PPP projects have improved the performance of the utilities around the world.

7.1.4 Why Does Water Fail to Reach Consumers in India?

The current institutional framework in India does not engender accountability (Araral and Ratra 2016). Since WSS in India is governed by a complex institutional structure, the responsibilities within the departments are fragmented, leading to even more problems. While WSS is a state subject, the center develops the overall policy and standards and directs investments in the sector. The state is then responsible for the development, financing, and cost recovery for regional WSS. Since the mid-1990s, there have been demands for reform of urban and rural water supply to the states. However, little thought or action has been given to the transfer of functionaries or funds.

7.1.5 Water as a Public Good

As per the UN, water is designated as a public good and access to water is regarded as a human right. One of the fundamental responsibilities of the state is to provide and maintain the access of water to everybody. Water service delivery in India continues to be marred by institutional challenges. There is a shortage of house-to-house connections, a lack of supply, and problems with poor quality.

7.2 Public Good and Private Investment

According to the Public–Private Infrastructure Advisory Facility database, sectors like transport, highways, energy, and telecommunications attract larger private investment in India (Table 7.2). The table shows that since 1990 only 4% of the projects by value and 16% by number have been in water and sewerage. However, most of these projects could not be successfully completed for lack of adherence to the contract conditions.

The Government of India recently announced cumulative investments worth €879 billion across infrastructure sectors over the next 5 to 6 years, which is expected to have a multiplier effect on the economy. However, a balance should be maintained between ownership, pricing, and governance.

Table 7.2: Infrastructure Projects across Sectors, 2016–2017

Sector/Subsector	Projects (number)	Total Project Cost (₹10 million)
Communication	2	26, 182
Energy	1,377	12,86,224.81
Cold Chain	13	3,278.95
Common Infrastructure for industrial parks	101	53,901.53
Education	15	1,213.49
Health care	9	938.02
Tourism	29	4,333.16
Transport	2,091	11,18,014
Water Sanitation	577	2,70,004.20

Source: Ministry of Finance, 2016–17.

7.2.1 Global PPP Investment Trends

Saha et al. (2018) reported that in 2017, "for the first time, investment commitments in emerging markets and developing economies (EMDEs) included backbone infrastructure for information and communications technology (ICT). PPI investment totaled $93.3 billion across 304 projects in 2017, an increase of 37 percent over 2016 levels. This significant increase in 2017 was mainly due to an unforeseen level of investment in East Asia and Pacific (EAP), which was driven by a few megaprojects in the People's Republic of China and Indonesia, as well as recovery in South Asia, led by Pakistan. However, total investment for 2017 is still 15 percent lower than the average for the last five years ($109.8 billion)" (p. 4).

7.2.2 Inefficient Public Delivery Imposes High Costs on the Poor

Currently state governments focus on expanding their resource base as opposed to efficiently managing supply and distribution. The cost of coping with unreliable water supply is highest on the urban poor since intermittent supply forces them to skip work and wait for water to arrive. This impacts women and children even more since they are the ones who are involved in these chores.

The responsibility of the local bodies is often restricted to supply through public standposts or delivering water through ad hoc arrangements such as water tankers. Guidelines under the recently announced Rajiv Awaas Yojna have accommodated these concerns and made the required provisions.

Some of the good practices in the water and sanitation sector are presented below:

- Strengthen governance and institutional machinery
- Improvement in management of information
- Environment sustainability and technology adoption
- Community participation and citizen service

7.3 Category I: Governance and Institutional Strengthening

Institutional capacity in the form of better management of facilities and improved local service delivery is essential. Some of these issues are addressed by the adoption of a PPP model. For instance, Nagpur Municipal Corporation manages the city's water supply on a long-term contract, while Surat Municipal Corporation (SMC) has addressed the issue of Non-Revenue Water (NRW) in a phased manner by creating a separate NRW cell.

7.3.1 Case #1: Surat—Formation of an NRW Cell (2006–2011)

Water Supply Scenario in Surat

SMC manages the water supply and sewerage system of Surat city. SMC's gross average daily water supply is about 980 million liters daily (MLD) translating to a per capita supply of about 147 LPCD. It has seven distribution zones: Western, Eastern, Central, North, South, Southeast, and Southwest, with 17 water distribution stations, four pumping stations and a distribution network of over 3,000 km. Surat has now implemented a new water supply master plan that is expected to cover the entire city and meet water demand up to 2041.

Creation of an NRW Cell

Between 2006 and 2007, SMC received 9,644 complaints related to leakages and 9,903 related to breakages. To address these issues, SMC planned to track all leakages. However, since these initiatives continued to lack the necessary institutional support, SMC deployed a cell in 2007 with the mandate to plan, develop, implement, and monitor an action plan for reduction of NRW, conducting periodic water audits, undertaking leakage mapping and repairs in a phased manner.

Objectives of the Cell

The NRW cell estimates the levels and then improves the overall level at 20%. The other objectives are:

- Enhance efficiency of transmission and distribution network
- Achieve equity in distribution and financial recovery
- Generate awareness for water conservation
- Periodic water audits (every 3 years)

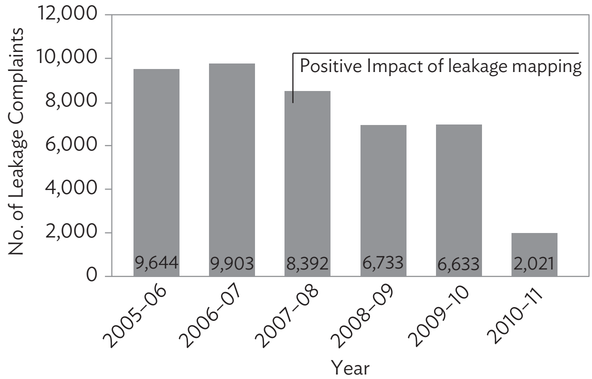
Leak Detection and Mapping Project

The leakage mapping exercise was carried out internally for Rander Gamtal area and the Central zone, and a few pipelines in the area were replaced stage-wise in 2010–11. After successful implementation in the Central zone and Rander Gamtal, the same initiative was extended to other zones of the city. After mapping leakages in all zones of Surat, changing the required pipelines, faulty valves etc. has been initiated. However, in the long run, SMC can adopt more efficient leak detection and repair techniques, and consider appointing an experienced private player.

Results

- **Reduction in leakages per km length of pipeline**: With the start of mapping, the number of leakages in water supply pipelines gradually reduced compared to previous years.
- **Reduced complaints**: The number of leakages dropped by 30% annually in all zones and accordingly the number of complaints received dropped drastically (Figure 7.1).
- **Better complaint tracking system**: Leakage repairs by all the zones were reported daily to the SMC head office, along with weekly reporting of the same to the Commissioner by the Engineering head (Table 7.3).

Figure 7.1: Impact of Leakage Mapping—All Zones, 2006–2011



Source: Surat Municipal Corporation.

Table 7.3: Number of Leakages and Contamination Spots

No.	Area	Frequent leakage spots attended (number)	Frequent contamination spots attended (number)
1	Central zone	22	13
2	Rander Gamtal	68	44
3	West zone (except Rander Gamtal)	7	0
4	North zone	23	19
5	South zone	33	11
6	East zone	11	12
7	Southwest zone	17	4
8	Southeast zone	4	7
Total		**185**	**110**

Source: Surat Municipal Corporation.

Best Practices and Replicability

Information gathered from the leakage mapping exercise helped create accountability and reduce water wastage. However, NRW reduction will require integrated planning, sustained institution building, and diligent process transformation. To ensure this, a city water supply network audit has been undertaken from 2017 to 2020. The water supply network status will provide crucial information for a master plan, indicating the areas where repair and restoration is required. The audit will mostly cover technical components of the network including design, aging infrastructure, selection of appropriate materials, quality of their manufacturing, quality of installation and construction, etc.

7.4 Category II: Information and Efficiency Improvement

A major constraint for the local bodies in India is the lack of updated information in the form of facilities, demographics, finances, coverage, or service levels. Information technology has recently been used to collect and maintain information; however, these efforts are still limited.

The Ministry of Urban Development (MoUD) launched the Service Level Benchmarking (SLB) initiative which indicated the quality of data available to arrive at service levels, and covered water, sanitation, solid waste management, and storm water drainage.

7.4.1 Case #2: Bangalore—Bulk Metering with Intelligent Operating System

The Bangalore Water Supply and Sewerage Board (BWSSB) installed bulk meters at strategically important locations and developed an ICT software to capture information from the bulk meters for effective decision making.

Status of Water Supply Infrastructure within BWSSB

Table 7.4 provides information on Bangalore's water supply. The major source of water supply to Bangalore city is the Cauvery river, from which it receives about 910 million liters daily. Water is treated at Torekadanahalli Water Treatment Plant (WTP). Water is pumped to the city reservoirs through three stages of pumping to the city reservoirs.

Table 7.4: BWSSB—Water Supply Overview

Description	Value
Service area	800.29 sq km
Population	9.5 million
Present demand	1,283 mld
Present supply	900 mld
Deficit	383 mld
Per capita supply	90–100 mld
No. of service stations	106
No. of water supply connections	623,000
Total length of water supply line	8,746 km

BWSBB = Bangalore Water Supply and Sewerage Board, km = kilometer, mld = million liters daily
Source: BWSSB 2017.

Need for Bulk Metering and System-wide Monitoring

In order to effectively manage the water supply system, BWSSB installed 218 bulk meters and received designated funding under the Jawaharlal Nehru National Urban Renewal Mission for this. In 2013, the Intelligent Operation of Water (IOW) software developed by IBM was installed to monitor and regulate the flow of water across the system.

The Initiative

Installation of bulk meters and monitoring system

In 2006, BWSSB prepared a detailed project report for procurement and installation of bulk meters and setting up a monitoring system for Bangalore's water distribution network. The project was sanctioned under the Jawaharlal Nehru National Urban Renewal Mission at a cost of ₹137 million. At the time of initiation of the project, BWSSB had six water supply zones.

Chetas Control System Private Limited was selected to procure and install the bulk meters. They also installed a monitoring system. Flow meters were installed strategically installed in locations on all ground-level and elevated-service reservoirs and on mains that feed water directly to the distribution network. Flow meters carried an ID based on the location and were geo-referenced. The flow meter measured the rate of flow of water at a given moment of time.

Online data management
An ICT application was installed to capture the data for analysis, decision making and online tracking and monitoring. IBM implemented a pilot project to install IOW in the state and ensure equitable distribution of water in different areas.

Global System for Mobile Communications interface
The bulk flow meters and the IOW system communicate using the Global System for Mobile Communications transmitters fitted to the ultrasonic bulk flow meters. The transmitters relay readings from the bulk flow meters to a mobile phone tower. A water information hub helps track leakages and other types of transmission and distribution losses. The software, customized for BWSSB needs, is based on IBM's Intelligent Operations Center and Integrate Information Core platforms.

BWSSB Best Practices

- The adoption of an integrated IT system helps to capture data on water supply and enables the operators to use it as a tool for decision making.
- The IT system also helps in collecting data on water flows and leverages their spatial distribution. This enables real-time information analysis for effective decision making.

7.5 Category III: Environment Sustainability and Technology Use

In India, wastewater management and finding sustainable ways to protect the environment is a major problem. There is an increasing demand on the water resources because of the growing population coupled with the management problems. These issues are being resolved by initiatives that adopt water conservation measures and focus more on wastewater treatment. The initiatives identified under this category include the Paradip Refinery project and the Karnataka Urban Water Sector Improvement Project.

7.5.1 Case #3: Paradip Refinery Water Supply Project (2016)

The Indian Planning Commission reports demand being driven by five major segments: fresh water supply, wastewater management, water recycling and reuse, desalination plants, and equipment (pipes, pumps, irrigation equipment). To tap into this demand, many large corporations have strengthened their presence, including Larsen and Toubro Ltd, Thermax Ltd, Ramky Infrastructure Ltd, Praj Industries Ltd, and VA Tech Wabag Ltd.

IL&FS Water Limited, an infrastructure firm that develops, finances, operates, and maintains water and wastewater projects, has several projects in its portfolio, which it operates through joint ventures and special purpose vehicles (SPVs). Among these is a joint venture with the government of Tamil Nadu, an SPV formed to develop the Tirupur Water Supply and Sewerage project, and one to develop the Paradip Refinery Water Supply Project for Indian Oil Corp. Ltd.

The project supplies water to Indian Oil Corporation's 5 MMTPA grassroots refinery and petrochemical complex set up near the port of Paradip in Odisha.[1] The water supply project consists of intake works at Cuttack, a 94 km pipeline from Cuttack to Paradip, a 100 MLD water treatment plant, and allied works at Paradip. The project is housed in the SPV IL&FS Paradip Refinery Water Limited.

Innovations and Impact

The project is the first of its kind wherein a major utility of a refinery has been awarded a build–own–operate–transfer model and has been implemented successfully. The process of obtaining ISO 14000 and Occupational Health and Safety Assessment Series certification for the project is currently underway. The entire facility is automated through supervisory control and data acquisition and a programmable logic controller. As a major portion of it has been laid underground, the 94 km pipeline has been completed with virtually no problems or displacement of people and livelihoods. The project also employs semi-skilled and unskilled workmen from the local community.

The project has initiated sand-dredging in the river, to be undertaken by Water Resources Department, to prevent flooding near the embankment and enable aquatic life to flourish. Compensatory afforestation has also been undertaken in a stretch of about 30 km. The Paradip Refinery, having been commissioned and commenced operations in March 2016 in a phased manner, was able to achieve 100% capacity utilization in May 2017.

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[1] In 2011, the Government of India approved the name change of the Sate of Orissa to Odisha. This document reflects this change. However, when reference is made to policies that predate the name change, the formal name Orissa is retained.

Community Benefits, Environmental Impacts and Sustainability

- To maintain an eco-friendly environment in and around its premises, Paradip Refinery has developed an ecological park in a large area that is integrated with rainwater harvesting ponds and provides a natural habitat for several species of rare local and migrating birds.
- A green belt is developed around the premises which houses different tree species. Regular water sampling is carried out in marine water to check water quality and to ensure the protection of aquatic life.
- A “plastic processing”-related skilling program is implemented to provide employment to families of Paradip Refiners, while also offering skill development courses.

7.5.2 Case #4: Karnataka Urban Water Sector Improvement Project (2004–2011)

Relevance of Design

In order to improve performance and provide sustainable services in Karnataka, the Karnataka Urban Water Sector Improvement Project components have the following objectives:

a) to assist the state government to finalize the policy reforms and to mutually prepare the business models;
b) to improve service provision, and attain continuous service in selected demonstration zones, thereby to improve the overall credibility of the project and also make the bulk supply operations, and distribution networks more efficient; and
c) to finance the project’s incremental operational costs, and studies related to project management and implementation, including acting as incremental, short-term consultants for the Karnataka Urban Infrastructure Development and Finance Corporation.

Achievement of Objectives (Efficacy)

Outputs
Studies and Technical Assistance: The following studies, designed to assist the government in launching its urban water supply, were completed, and the recommendations have been, or are expected to be, implemented:

- A proposal to set up the Karnataka State Urban Water Supply Council has been elaborated and is pending government approval.
- A study on strengthening service delivery in urban local bodies has been completed, but the recommendations were not deemed feasible by the government. The World Bank-implemented Water and Sanitation Program has been contracted to revise the recommendations.
- A water and sanitation information system has been developed and is being used.
- A study for the establishment of the legal and regulatory framework has been completed, but the recommendations were not deemed feasible by the government. The Water and Sanitation Program has been contracted to revise the recommendations.
- A social awareness communication strategy to convince residents in the five demonstration zones of the feasibility of continuous water supply and the importance of consumers paying for water provided has been implemented.
- A volumetric tariff policy based on customers' actual consumption as measured by water meters has been adopted and implemented.
- Initial drafts of city-wide engineering and feasibility studies, transition plans, and other studies related to the use of public–private participation in the operation of the systems have been completed. Financing of these works after project closure is planned to be assumed by the government.
- A planned study to prepare for urban water supply legislation was not completed. It was unnecessary since the legislation was already included in the broader decentralization agenda.

Physical Outputs: Civil works and goods procured and successfully implemented were:

- Water distribution network: The project installed 238 kms of the water distribution network, including house connections, and repaired customers' water meters in the five demonstration zones covering more than 25,640 new house connections.
- Water meters: As part of the work to address priority bottlenecks and increase bulk supply, the project implemented 11 investments resulting in significant improvements in water delivery in the three participating urban local bodies through the reduction of leaks and the rehabilitation of production, transmission, and storage facilities. In addition, water meters were procured and installed in all five demonstration zones.

Outcomes

The government's Urban Water Supply Policy achieved the following outcomes:

Improved Water Supply Delivery: The possibility of continuous water supply was successfully demonstrated with good water pressure available 24 hours in all five demonstration zones due to the implementation of the physical investments. Prior to the project, the baseline level of service was about 1–2 hours every 2–3 days in the demonstration zones.

Sustainability: Managerial capacity, institutional structure, and accountability for water and sanitation operations for the participating urban local bodies have been enhanced as shown by the increased quantity of water available to consumers in the five demonstration zones, the design and implementation of volumetric tariffs, and the associated community awareness.

At appraisal, it was reported that none of the participating urban local bodies were able to recover even half of their O&M costs from the tariffs. The project established a cost recovery mechanism to ensure that revenues in the demonstration zones would cover 80% of the O&M costs and achieve a billing and collection efficiency of at least 70% by the end of the project. At the conclusion of the project, the billing and collection efficiency was 83% and cost recovery was 119%.

Collection efficiency exceeds national benchmarks based on a sample of 28 cities in 14 states, where the average collection efficiency was 60% (versus 83% for the project demonstration zones) and the coverage of O&M costs was 67.2% (versus 119% for the project demonstration zones). This information comes from a study made in 2010 of the first Service Level Benchmarking Data Book and released by the Ministry of Urban Development.

Increased consumer awareness, commitment, and ownership for reform were attained as reflected in consumer willingness to pay. This was evidenced by the efficiency of revenue collection which was due to the improvements made in increasing the supply of water and the introduction of volumetric billing.

Efficiency: Technical water losses were reduced through the physical investments, metering, technical assistance in designing a new tariff structure, and support from the consumers. Technical losses in the demonstration zones fell from a baseline of about 50% prior to the project, to about 7% after the project.

While no baseline data exist for total non-revenue water in the demonstration zones, the combination of the low (7%) technical losses with the average billing and collection efficiency of about 83% means that the actual level of total non-revenue water is about 23%, which is acceptable by international standards. It also reflects increased consumer awareness, which has reduced the losses due to illegal connections, though this reduction has not been quantified.

Commercial Orientation: The use of private operators was tested by the project and determined to be successful. The use of private operators has become standard practice throughout the state and it has been adopted in other states.

Efficiency of the Project

The economic internal rate of return (EIRR) for the project increased from 16% at appraisal to 29% at completion. The EIRR was calculated for investments (in subcomponents B1 and B3), representing about 84% of the total project costs at closure. At appraisal, the estimated EIRR for priority investments (component B1) was 18% based on the benefits coming from an increase in the bulk water supply, and power savings as measured by the bulk water meters installed by the project. The 30% EIRR at completion was due primarily to the larger-than-expected increases in bulk water supply.

At appraisal, the estimated EIRR for demonstration projects (component B3) of 14% increased to 28% at completion primarily due to the focus group discussions having increased the savings achieved in minimizing coping costs (costs of gathering and carrying water) from ₹350 ($7.16)/household/month to a net of ₹771 ($15.78)/household/month. Time savings from fetching and carrying water is a major economic benefit for water supply projects since the time saved can be used for economic activities.

The project was also successful in implementing the agreed-upon investment program for a lower cost than had been expected at appraisal, because:

a) The operator used more cost-effective piping (high density polyethylene) in the demonstration zones instead of the more traditional and expensive piping (a combination of cast iron and polyvinyl chloride)
b) The delivery of the required service improvements was achieved without the need for any additional expenditure due in large part to the use of experienced private sector operators who were able to introduce efficiencies which had not been estimated at appraisal.

On the negative side, there was a 27-month implementation delay, much of which was due to administrative inefficiencies. However, in view of the improved economic return and lower costs, efficiency is assessed on balance as substantial.

7.6 Category IV: Citizen Participation and Awareness

Citizen participation from the beginning of the project helps project authorities consider the community issues and take their point of view into consideration. Another benefit of citizen participation from the beginning is less likelihood of protest from citizens during the implementation phase. Local bodies have been able to gradually become facilitators instead of just service providers. Cases in this category highlight some of the best practices where the project success can be directly credited to public participation.

7.6.1 Case #5: Tirupur ZLD Effluent Management Project (2010)

The implementation of India's first large scale PPP water supply project and the world's largest zero liquid discharge (ZLD) system helped improve water conditions in Tirupur, one of India's top industrial clusters. IL&FS played a pivotal role in this epic journey spanning two decades, which Global Water Intelligence UK has called, "a phoenix rising from the ashes of an environmental catastrophe".

Dollar City

In India, Tirupur is synonymous with garment manufacture: for 30 years it has been called the "knitwear capital of the country", or simply "dollar city". With $3 billion worth of exports in the last year, Tirupur accounts for 90% of the cotton knitwear that India exports. Nike, Reebok, H&M, and Tommy Hilfiger are only a few of the global behemoths that source their wares from this South Indian town.

But soaring success and tragedy have never been too far apart here. A dry region with no perennial river, Tirupur was originally a rain-dependent agricultural economy. Repeated crop failure prompted a shift to cotton trade in the 1960s, then to the production of low-value cotton hosiery until the 1980s.

Industry Booms but Water Runs Low

Tirupur is home to 2,500 knitting units, 580 dyeing and bleaching units, 300 printing units, 150 embroidery units, and nearly 200 other ancillary units. Already a huge contributor to India's export economy, and an industrial town that directly employs 700,000 people, Tirupur is in the throes of a new water crisis.

To households, the municipality supplies water for a just a couple of hours once every 3 or 4 days—sometimes as little as once in 10 days. Industrial units, which depend on water for bleaching and dyeing processes, receive no municipal water supply. They were digging as far as 50 km away and transporting the water back in tankers.

The depleting groundwater was not clean; effluents from the dyeing industries have rendered it so polluted that it must be treated, at huge cost, even for industrial use. Moreover, as only one in two Tirupur garments is meeting customer specifications—an abysmal right-first-time ratio—the industry is incurring the production cost of two items for the sale of one.

Genesis of a Unique PPP Endeavor

The Tirupur Exporters' Association (TEA) along with government officials approached IL&FS to assist in realizing the dream. Built on the vision that the private sector can become an instrument of state for the development, implementation, and management of large scale infrastructure projects, IL&FS came up with a PPP model.

The Government of Tamil Nadu, IL&FS, and TEA became the first stakeholders for the New Tirupur Area Development Corporation Ltd, the SPV that would bring this project to fruition. This was to become India's first water infrastructure project to be implemented on a PPP basis. The scope of the project covered:

a) catering to the needs of the industrial units but also the wayside villages and the households in the Municipality of Tirupur;
b) integrating a scheme for the collection of sewage and its treatment and disposal to sustainably deal with the massive water supply;
c) asking industries to commit to a zero-discharge effluent treatment scheme; and
d) predicating recovery of the investments on user fees via cross-subsidies, with the municipal households being charged only a fraction of the industrial fees.

Bringing All Stakeholders on Board

Liberalization had only just opened up the Indian economy, and the idea of private sector involvement in infrastructure, especially in the water sector, was a very sensitive issue. The stakeholders were many and diverse; enormous time and energy was spent on studying, discussing, and balancing their needs.

Citizens needed to be convinced of the affordability and benefits of the idea, while industry had to be convinced about the charges and the need for paying a price to be environmentally and socially responsible. The government had to be convinced that regulations and enforcement were key to making such an initiative successful (even if it supported private investments in the infrastructure sector), and that project costing on a life-cycle basis was far cheaper than minimizing up-front capital costs. Lenders and investors had to be convinced to invest in a project where no safety net from the government was forthcoming, and to base their support on customers' willingness to pay.

In a major achievement, IL&FS succeeded in raising money from US capital markets for the project through 30-year bonds. This made the water tariffs more affordable than they would have been through the standard 7- to 10-year period to amortize the project investment.

Benefits for Everyone

The New Tirupur Area Development Corporation built the 65 km pipeline from the Cauvery river, and provided water supply and low-cost sanitation infrastructure for the villages along the line. Tirupur, which previously had neither a sewerage system nor a drainage system, now received 118 km of sewer lines, four sewerage pumping stations, one 30-MLD capacity waste treatment plant and 36 low-cost toilets.

Challenges

With 60% of the city connected to the sewerage system, Tirupur was now one of the best covered in India. Industrial and domestic water supply to the doorstep was available every alternate day, soon to be available daily. Community self-help groups helped others to construct and maintain the cleanliness of the low-cost toilets. The industries, now free of water-related concerns, could focus on expanding their businesses and meeting global competition.

Despite their commitment, industries continued to dump their untreated waste into the Noyyal river, making pollution levels unbearable. The effects permeated to agriculture; when they could no longer be ignored, farmers petitioned the courts. In 2006, the court ordered the industries to either set up ZLD or face closure.

The lack of technology and experience in the ZLD area worldwide bogged down the Tirupur treatment plants; they faced particular problems with the thermal evaporation of the brine residue from the reverse osmosis systems. In 2011, all the dyeing units of Tirupur were forced to shut down, handicapping the entire garment industry.

Technology Innovation toward Zero Waste

Tamil Nadu Water Investment Company Ltd, a Joint Venture between IL&FS and the Government of Tamil Nadu, stepped in, this time with the highly innovative Treated Brine Reuse Technology.

This technology makes it possible to recover and sell 90% of the sodium sulphate reject from the recovery treatment facility. In addition, 98% of the recovered water can be reused after the removal of brine. Not only does this take the industries close to a ZLD status, but makes the technology commercially viable as 50% of the treatment plant's costs are recovered in the process.

Discharge of dyeing effluents into the river was completely stopped. IL&FS thus brought the industries back to their feet stronger, cleaner, and more productive.

The Tirupur project is an extraordinary testimony to power of partnerships. First, government and industry collaborated to bring in IL&FS as a specialist infrastructure institution to help develop and implement such a project on a commercial basis. Then, the Government of Tamil Nadu and IL&FS collaborated to develop and establish a sustainable framework to raise monies and procure the technical consortia to build the project. The Tirupur plant went on to become the world's largest ZLD Common Effluent Treatment Plant.

Best Practices and Impact

Thecholesteryl ester transfer protein reuses 95%–98% of the water and 70%–80% of the salt from the wastewater, for reuse in the dyeing process, ensuring commercial viability. The direct re-use of treated brine in the dyeing process reduces the need for the thermal evaporator system. The application for patenting the Treated Brine Reuse Technology is underway.

The project has encouraged industry to monitor water usage and promote recycling. As water demand by industry is reduced, more water is made available for agriculture and domestic demands.

The project ensures sustainable growth while meeting the most stringent regulatory norms. It has been named the Industrial Water Project of the Year 2014 by GWI UK, and 2014 Water Reuse Industrial Project of the Year by Water Reuse Association USA, and has also received the 2030 WRG Corporate Water Stewardship Award from GWI Athens.

7.6.2 Case #6: Fish-farming in Odisha

IL&FS extends support to the Odisha farmers to transform their submerged paddy fields and be able to have higher yields of fish and vegetables. Hugging the coast in Odisha, about 200 kms north of the state capital Bhubaneswar, lies Balasore district. Perennial and estuarine rivers crisscross through the region before emptying into the Bay of Bengal. Dotted with universities and engineering colleges, Balasore town boasts an average literacy rate of 88%, far higher than the national average—it is Odisha's most literate town. But the district's main occupation is paddy farming.

The area struggled with poor water quality, open defecation, and poor sanitation. With the involvement of the community in fish farming, farmers were able to overcome water insecurity. Aquaculture can empower communities and allows them to develop safe drinking water sources, preserve the resources, and develop partnerships with the private sector for providing purified water for drinking purposes at affordable prices.

Citizen Partnership

Ranjan Bhadra is a paddy farmer in Balasore. He lives with his wife and two children in a dilapidated house on his acre of land. His teenage daughter will soon finish high school. His 14-year-old son is mentally challenged. Ranjan's ancestors have traditionally cultivated paddy. But every monsoon, the fields get flooded and the crop is submerged. An acre's yield provides Ranjan's family only about ₹5,000 a year.

Archana Ghadei's family owns half an acre of farmland and a small pond. Her husband, a migrant mason, is usually away from home. She has a 12-year-old daughter who she sends to the government school, and a mother-in-law whom she has to look after. Every year she too sees her fields submerged and half her crop lost.

IL&FS took note that the paltry incomes were a recurring story in every rural household in the region as heavy rains regularly bring floods, submerging fields and destroying crops. IL&FS Transportation Networks (ITNL) was working in Balasore to repair and reconstruct a 120 km stretch of the National Highway between Kharagpur and Balasore. ITNL surveyed the catchment area in order to identify potential environmental and socio-economic impacts of the project. Based on a comprehensive survey, many interventions were developed for the area, with a specific focus on improving livelihoods.

Discovering a New Livelihood Opportunity

Nalanda Foundation, then called the Social Inclusion Group of IL&FS, discovered that in the submerged fields and unmanaged ponds of Balasore there lay a substantial livelihood opportunity. Nalanda Foundation approached Dr. Munir Ahmed, a renowned fisheries scientist from Bangladesh, who pointed out that the submerged areas could be converted into fish and vegetable farms. Balasore district was importing more than half of its fish requirements from neighboring states—the potential for aquaculture was huge.

IL&FS officials held meetings with SPARSHA, an active local nongovernment organization that had gained the trust of the farmers through its earlier Agricultural Productivity workshop. Detailed plans were made in consultation with some of the farmers, who helped identify land that could be used for the new farming program.

Traditionally, the villagers only farmed fish for domestic consumption, using poor seeds from local vendors. Therefore, a pilot training program was initiated with 39 farmers from eight villages. The success of the pilot program was established and systematic plans to scale the initiative across the district were developed. Parameters to determine the success of the program and the evaluation of impact through third-party agencies were also set up. A detailed plan for the buy-in and capacity-building of the local farmers was also developed.

Training Farmers for Aquaculture

The villagers farmed fish for domestic consumption, or occasionally sold it during festivals. Fish seeds were bought from local vendors on bicycles, with no idea of breed or quality. As a result, the fish growth was poor and productivity unstable.

IL&FS trained the farmers to correctly identify the fingerlings, taught about the right feed for healthy fish growth, and demonstrated best practices to harvest, and ways to keep the fish fresh for the market. They were also taught how to maintain the health of their pond ecosystems, from the quality of water to layering of fish species. Among other technical inputs, Dr. Ahmed shared his expertise of making low-cost ponds in submergence-prone areas. Local fishery-scientists from Odisha also conducted training programs. The farmers were learning in classrooms as well as in the field. They were taken to visit commercial freshwater fish farms.

Based on the farmers' plans, IL&FS helped convert some wasteland into new ponds (*ghers*), and renovated the existing ponds that had been neglected. Soil and water quality was tested, and the ponds were treated so they were suitable for freshwater fish cultivation.

SPARSHA helped the farmer groups make detailed schedules for the fish farming cycles and source quality fingerlings and feed, and access financial aid. The local fishery experts would make monthly visits to the farms to monitor progress; the farmers could also get in touch with them over the phone at any time if they had questions.

Organizational and Financial Literacy: Skills for a New Future

The male farmers of Balasore had never before formed an organized group. Now, through games and role-play activities, they were mobilized to make Farmer Producer Groups. They were assisted in opening bank accounts, and trained in financial literacy. Archana, the only woman in the group, received support from her family and consistent help from SPARSHA, and gradually gained the self-confidence to undertake this new endeavor. Equipped with the skills for fish-farming, and initiated into bookkeeping and record-management, the farmers were ready now future-ready.

Shah (2017) argued that skills acquisition enables, "'personal growth' and 'development/progress'", and, "[e]mpowerment is seen as a path out of poverty" (23).

Vegetables on the Side

While fish flourished in the seasonal *ghers*, the farmers were encouraged to grow vegetables and fruits on the bunds at the edge of the ponds. Okra, tomato, pumpkin, bitter gourd, papaya and banana are just a few of the things that now populate these bunds, helping the farmers hedge the risk of lean periods. Some farmers earned as much as ₹50,000 from the area around a pond just from the vegetables.

A year into scientific fish cultivation, villagers are convinced of the benefits. With the profits from his one acre of *gher*, one villager has been able to buy himself a scooter, repair and renovate their home, and still save more than ever before for his family. In 2018, he wants to convert another acre of his land for fish and vegetable farming, so he can better look after his son and send his daughter to college. Archana has set an example in her village by becoming the first woman fish farmer. With a green thumb for vegetables too, she is buoyant in her success. The Balasore initiative has motivated the IL&FS Group to continue to actively seek livelihood-enhancing activities in all its catchment areas. The positive energy that such successes unleash inspire employees to be more sensitive to local constituencies (Shah 2018). It prompts management to internalize the externalities of their actions, and organizations to approach their businesses in a more holistic and meaningful way.

This case highlights that poor and small communities can manage and take charge of the O&M cost. The community's long-term support, along with institutional service, is key for sustainable service delivery Shah (2016). Household connections help women pursue productive activities. Toilets provide privacy and convenience to women.

The incorporation of livelihood training like fish farming, social forestry, masonry, and plumbing in the support programs can help communities meet the capital and O&M costs (Shah 2019). These are also crucial policy incorporations that should be considered for long-term sustenance of rural communities.

7.7 Conclusion

The most urgent challenge that countries today face is to double food production by 2050 to feed the growing population. This change is magnified because of the impact of climate change combined with increasing climate variability and water-related disasters.

This chapter recognizes that improvement in the water and sanitation conditions in India are affected by poor institutional, operational, and financial management. The current Government of India approach toward water supply and sanitation policies continues to focus on decentralized solutions, rather than piped sewerage and centralized treatment. It is imperative to have a more community-driven approach. There is also a need for an autonomous regulatory agency to manage the growing concerns over water and sanitation at the state or national level compared to the current highly decentralized approach.

There is a need to increase awareness regarding links between sanitation and public and environmental health issues while promoting integrated city-wide sanitation. There is also a need to promote network-based systems for better implementation of policy interventions. Practices from successful projects across the country can be considered good. The cases covered in this chapter highlight the benefits of a dedicated policy, renewed institutional support, and focus on financial sustainability and citizen involvement. With these changes in policy and other areas of management, the issue of water and sanitation service delivery can achieve better outcomes in a small period of time.

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8

Distributional Equity in the Urban Public Water Supply in Kathmandu, Nepal

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8.1 Introduction

Water security is recognized as a human right (United Nations Resolution 64/292 2010), with governments being held responsible for providing every household with affordable, sufficient, and safe water and sanitation services. Although government piped water networks are available in some developing cities, supply is often intermittent, with restricted hours in different areas. Public utilities are unable to provide piped water to whole populations because of their inability to recover costs, low tariffs, management inefficiencies, and unresponsiveness to the needs of the underprivileged (Bakker 2010). Even though records published by governments focused on the Millennium Development Goals document increased the number of installed facilities or extension of piped water services, these networks are not always operational (ADB 2013). Therefore, while governments in developing countries have invested in large municipal water supply systems over the past decades, no improvement has been observed (Bakker 2010).

The degree to which urban water resources are equitably distributed in developing cities has serious implications on the health and socio-economic development of the people (Kulinkina et al. 2016). Public water supply in South Asia is deficient in terms of availability, accessibility, quality, and equity (Jacquet, Pachauri, and Tubiana 2010). No South Asian country successfully provides water for the whole urban population, while in sub-Saharan African cities, the public utility directly serves usually less than half the population (Ruet, Zérah, and Saravanan 2002; Grönwall, Mulenga, and McGranahan 2010; Adelana et al. 2008; Hadipuro and Indriyanti 2009). An assessment by the United Nations

Center for Human Settlements estimated that 970 million urban dwellers in Africa, Asia, and Latin America and the Caribbean are without access to adequate water supply (UN Habitat 2006). Further, there is evidence that poorer households tend to not even be connected to the government piped networks (UN Habitat 2003b, 2006; UNWWAP 2003; UNESCO 2006), with those that are connected being subject to intermittent water supply. Therefore, at the regional scale, the Water Security Index confirms South Asia as a hotspot where populations and economies are being adversely impacted by poor water security (ADB 2013).

Addressing this lack of universal access to urban water supply, especially for marginalized communities, has been high on the agenda of the international community. Yet, despite the sustained and significant investment by bilateral and multilateral aid and financial agencies, the issues of poor water supply coverage, decrease in the quantity of water, as well as deterioration in the quality of water (in terms of microbial contamination and hazardous levels of chemicals, such as arsenic and fluoride) have persisted (WHO and UNICEF 2000; UN Habitat 2003a; Solo 1999; Budds and McGranahan 2003; Hardoy, Mitlin, and Satterthwaite 2001; Anton 1993; Bakker et al. 2008).

There are several aspects that have been explored in the larger literature on who benefits and why in the provision of urban services and facilities. One line looks at the causal factors in the distribution of services (Araral and Wang 2014; Lineberry 1977; Mladenka 1989; Meier, Stewart, and England 1991; Boyle and Jacobs 1982) from which three critical factors emerge. First, are there physical factors such as the geography, topography, hydrology, or climatic factors that influence the spatial distribution of water? Second, are there demographic factors, such as education (Mahama, Anaman, and Osei-Akoto 2014), ethnicity, income (Smith and Hanson 2003; Bosch et al. 2002; Wright, Gundry, and Conroy 2004; McGarvey et al. 2008) and whether the household lives in squatter settlements/slums or formal housing areas (Gerlach and Franceys 2008)? These relate to the ease with which people can obtain water and how affordable it is. According to Bosch et al. (2002), lower educational achievements reduce the capacity of individuals to demand better services, as they are considered to have less power in society. More educated individuals are also likely to be better informed or more able to process available information, thereby enhancing their probability of having access. Last, are there political and institutional factors, such as government capacity and willingness to invest in and develop infrastructural facilities, implement and monitor regulation on standards of water quality, etc. (Araral and Yu 2013; Holden 2013)?

This stream of literature also aims at analyzing whether politics or other factors, such as standard operating procedures or rationaltechnical considerations, account for the inequities. It has also led to a theory on unpatterned inequality, which states that, "when distributions are inequitable, there is no systematic underclass bias..., [and] unpatterned inequality is the result of bureaucratic decision rules and routines coupled with idiosyncratic historical events" (Koehler and Wrightson 1987: 81). Therefore, who governs has little effect on the equity outcomes, especially at the level of municipal service distribution. However, this view is debated, since many believe that distributional inequity stems from inappropriate and politicized policy processes, especially electoral and regime politics (Miranda and Tunyavong 1994).

Urban services can be categorized into four types based on their social function—routine, protective, developmental, and social minimum (Lucy, Gilbert, and Birkhead 1977). Water supply is part of the routine services since everyone, regardless of gender, age, or socio-economic status, uses it regularly. Similar services include sewage collection and disposal, as well as transportation. These are also not considered purely public goods, as access can be limited through the application of fees and charges. According to Lucy, Gilbert, and Birkhead (1977), for these types of services, providing equal access would have direct impact on equal outcomes. Further, minimum levels of service in terms of quality and quantity are essential. In the water sector, approximately 50–100 liters per person per day is deemed sufficient to minimize the health risks associated with poor hygiene (WHO 2011). Government water is always cheaper than other private options (Mahama, Anaman, and Osei-Akoto 2014), and so, affordability is usually not an issue in this case.

The existing literature on distributional equity in urban water supply is largely published in reports by international agencies (UN Habitat 2003b, 2006; UNWWAP 2003; ADB 2013) that look at whether or not a household is connected to the government piped network system (Miranda and Tunyavong 1994). This is also seen in the few journal articles that look at differences in access to domestic and drinking water in the urban context (Araral and Wang 2013; Soares et al. 2002; McKee et al. 2006; Yang et al. 2013; Mahama, Anaman, and Osei-Akoto 2014; Hopewell and Graham 2014).[1] SDG Goal 6 also aims to "achieve universal and equitable access to safe and affordable drinking water for all" by 2030. This is a limited way of looking at distributional equity in the context of developing cities, because most water systems suffer from unreliable and intermittent supply (Kumar 1998). This means that water

[1] Equity in the water sector, in peer-reviewed literature, is studied primarily in the context of privatization and effect of different pricing policies (Cooley and LaCivita 1979; Rogers, de Silva, and Bhatia 2002; Ruijs, Zimmermann, and van den Berg 2008; Barberán and Arbués 2009; Birdsall and Nellis 2003; Bayliss 2002).

is provided only for a limited number of hours on a limited number of days, which can vary across regions, cities, and even within different parts of the same city. Hence, while the connection may exist, the water may not be safe or in quantities sufficient to meet basic health needs.

This is reflective of a focus on policy outputs in the existing literature as opposed to policy outcomes. Policy outputs can be conceptualized as the activity patterns of municipal authorities (Fisk and Winnie 1974), whereas policy outcomes are the effects that specific government activities have on related social conditions (Ostrom 1974). As the discussion on water connections suggests, outputs do not necessarily have a direct impact on outcomes (Rich 1979), but they provide a basis to start evaluating the adequacy and effectiveness of public services. A mere focus on outputs can potentially conceal greater inequities in the system. For instance, in the case of water supply, differences in quantity and quality are essential to be examined because they have a more immediate impact on the water consumption and health of households, especially those that are poor or marginalized. Hence, it is difficult to draw comprehensive conclusions about the equity of an urban service distribution system without the consideration of outcomes.

From the literature review, it is evident that there is insufficient research on the inequities of the public water system, especially studies that measure beyond having a connection to the public utility system. There is a need to assess not only formal government action but also the effect of it. Only then is it possible to know whether the policy is having the envisioned impact and that the implementation is being carried out fairly and equitably across the intended beneficiaries. Hence, in the case of water supply, it is equally important to evaluate whether socio-economic factors play a role in the amount or quality of water delivered among those who have access, because these two aspects assess the distribution outcomes more accurately.

Overall, in Nepal, access to piped water in urban areas has declined from 68% to 58% from 2003 to 2010 (Muzzini and Apariccio 2013). This is because the pace of urban growth has been much faster than the rate of expansion of the piped water network. Within the country, the capital city is reported to have poorest system of water supply (Muzzini and Apariccio 2013). The Central Bureau of Statistics (2012) of Nepal reported that two-thirds of the urban population in Nepal do not have an adequate supply of water and one-fifth of the households do not have access to a domestic water source.

Using primary data based on a 1,500-household survey conducted in 2014, this chapter focuses on examining the distributional equity of the urban public water supply system in Kathmandu, Nepal, by assessing both the policy output as well as policy outcomes. The specific questions addressed in this research are:

a) Do wealthier households have greater access to the government piped water network than poor households?
b) Does the quantity of water delivered through the government piped water supply system differ between poor and nonpoor households?
c) Does the quality of water delivered to households differ between the poor and nonpoor households?

The chapter is structured as follows. Section 8.2 provides the background of the study location and the state of the public water supply system. Section 8.3 provides the theoretical background to the concept of equity that is used in this chapter and the way it is applied in the context of government water supply. Section 8.4 describes the data collection methods and methodology utilized in the study. Section 8.5 provides an overview of the water consumption across different households in Kathmandu based on the survey results. Section 8.6 explains the results of the regressions and finally, the last section discusses the results and concludes.

8.2 Background

Nepal is one of the least urbanized countries in the world, with only 17% of its population living in urban areas. However, it also has one of the highest urbanization rates, with a 6% growth rate on average per annum of its urban population since the 1970s (UNDESA 2012). This rapid growth has occurred during a prolonged period of political instability. Until the recent local elections in 2017, none had taken place since 1997, and so even the capital city of Kathmandu had been functioning without a local government. Bureaucrats were running the city with little or no accountability to the people. The Maoist insurgency that ran from 1996–2006 led to a large influx of migrants from rural areas to Kathmandu, a trend that the government was not able to adequately manage, and which led to the current chaotic state of unplanned development. Kathmandu has, therefore, grown to be an urban sprawl of 2.7 million people (Central Bureau of Statistics 2012), facing a growing list of issues from air and water pollution to traffic congestion and inadequate water supply and sanitation systems.

The piped water system in the Kathmandu Valley was introduced in 1891, with the purpose of serving the rulers and elites. In 1928, the system was expanded to reach the general public. In 1972, the World Bank gave a loan to the Nepal government to improve urban water supply and wastewater services. Through this loan, the Water Supply and Sewerage Board was formed in 1974, which was renamed the Nepal Water Supply Corporation in 1989. It was eventually devolved into three separate organizations in 2006 with the passing of the Kathmandu Valley Water Supply Management Board Act. Since then, the Kathmandu Upatyaka Khanepani Limited (KUKL) has been designated as the sole service operator that is responsible for providing water and sewerage services to the people of the valley. The KUKL has estimated that the daily demand for water is around 360 million liters; however, supply is approximately 76 million liters a day in the dry season and 123 million in the rainy season (KUKL 2014). This inadequate supply can be attributed to the lack of capital investment in extending the services to the growing population in the city, as well as under-maintenance of the existing assets.

The supply system in Kathmandu includes another three sources of household water. First is the traditional water system that developed during various times in the ancient period and comprises stone spouts, dug wells, tanks, and ponds. Several of the traditional sources, such as communal tanks, are no longer functional. Second are private wells that allow households and industries to extract groundwater directly for their needs. Lastly, there are the informal private water vendors who supply drinking and household-use water through various means to the households for a price.

To overcome the water shortage, the long-term plan of the government has been to divert water from the Melamchi River outside the valley and deliver it to Kathmandu via a 26-km tunnel (Dixit and Upadhya 2005). This effort has been delayed by almost 2 decades, as it was initiated in 2001; as of January 2019, the project is still incomplete (Mandal 2019).

This context is similar to several other developing cities that face common constraints to improving their municipal service provision, such as turbulent political environments, high levels of corruption, low bureaucratic capacity and a focus on technically expensive solutions. Therefore, they lack the institutions that are needed to support good delivery of public services.

8.3 Operationalizing Equity for Examining Public Water Supply Systems

Equity is an important concept that can be used to evaluate the fairness and effectiveness of a distribution system (Rawls 1972). It attempts to identify what is socially just and aims to address unequal outcomes (Walzer 1984; Sayed 2000). Since the concept can have different interpretations in different contexts, it is considered complex and multidimensional in nature (Berne and Stiefel 1984; Chi and Jasper 1997). Equity is also seen as a normative concept, where its measurement (i.e., the differences or inequalities between individuals or groups) is based on empirical testing.

To conduct an empirical estimate of equity, it is essential to operationalize the term. In the literature, there is no uniform way of doing so. Therefore, in the context of water distribution by the public supply system, this chapter uses the concept of distributive justice, which refers to the fair allocation of good in society. A socially just way considers not only the total quantity but also the process and patterns of distribution. Armstrong (2012) defines it as the distribution of the benefits and burdens of a society. Principles of distributive justice tell us how these benefits and burdens ought to be shared or distributed.

This chapter is based on Aristotle's principles of distributive justice that differentiate between horizontal and vertical equity (Roemer 1998). Vertical equity requires that the net fiscal burden should increase with individuals' capacity to pay (Wagstaff and van Doorslaer 2000). This aspect cannot be measured in this chapter because the public water utility pricing is standardized at the city level and depends on the amount of water consumed. Therefore, no variation based on socioeconomic factors is expected.

According to the idea of horizontal equity, people who are equal with respect to certain characteristics should be treated equally. This implies an absence of discrimination among individuals who are similar in all the relevant characteristics (Wagstaff and van Doorslaer 2000). When applied to the case of public water supply, equity in water service provision would mean equal physical access to the service and equality in the quantity as well as quality of water supplied across different communities and varying income levels.

For horizontal equity to exist, all households should have an equal opportunity to get water from the public water supply system, should they need to, and there should be no difference in access based on household characteristics or place of residence. Access to water is the most basic equity concern because survival, regardless of quality, cannot occur without it. This should be possible irrespective of gender, socioeconomic status or ethnicity. It is considered important because enabling households to have access to resources puts them at a fair starting line and allows them to obtain sufficient water.

Secondly, water consumption in quantity as well as quality should be equal across households. Merely having access is not sufficient if the government favors the wealthy by providing them with water more adequately, reliably, and safely. The financial burden on poor households increases substantially if they get insufficient water from the public utility, since it is consistently cheaper than having to purchase it or investing in other private means of water collection, such as wells.

Therefore, if the public water supply is horizontally equitable, then factors such as ethnicity, income, or location would not mediate the accessibility, availability and quality of water to a household.

8.4 Data Collection and Methodology

The data used in this chapter were drawn from a household survey conducted in the Kathmandu Valley of 1,500 households across the five municipalities—Kathmandu, Lalitpur, Madhyapur, Kirtipur, and Bhaktapur. It was a part of a re-survey conducted of 1,500 households selected in 2001 based on a multistage clustered random sampling procedure (Pattanayak et al. 2005). Clusters were located using aerial maps provided by the Central Bureau of Statistics for the 1996–97 World Bank Living Standard Measurement Survey for Kathmandu. In Kathmandu, Lalitpur, and Bhaktapur, a previously conducted complete enumeration of all households was used as the sample frame (SILT-DRTC 1999). In Kirtipur and Madhyapur, the 1991 population census was used as the sampling frame.

Wards (the lowest administrative level of Nepal) were then selected from the sampling frame based on a probability-proportional-to-size sampling approach that ensured households had an equal opportunity of being included (Babbie 1990). After a ward was selected for inclusion, sub-wards were drawn randomly. The final sample consisted of 60 clusters of 25 households, each covering all five municipalities in the Kathmandu Valley. If a cluster was selected for inclusion in the sample, then all 25 households in that cluster were interviewed for this study. Since probability-proportional-to-size sampling depends on the size of the population, some wards had more than one cluster in the final sample. Further details on the questionnaire and survey methodology are available in Appendix 8.1.

From the equity framework developed above, three outcome variables are relevant: a dummy for whether a household can access a government piped water connection, the quantity of water obtained from this connection (in liters per day, if they have access) and the perceived water quality of the piped water (ranging from low to serious health risk perception). In the study, each of these variables was analyzed using regression models. Appendix 8.2 details the analytical and empirical strategy and explains the choice of regression models, as well as other control variables used in the study.

The key explanatory variable of interest was the household wealth group, which was estimated using an index based on key asset ownership and housing characteristics, following the principal component analysis method of Filmer and Pritchett (1999). It included aspects such as house characteristics, construction materials used in the houses, access to utilities, and ownership of selected durable assets. Using the wealth index values, three groups were created: richest 20%, middle 40%, and poorest 40%. An asset-based indicator was chosen for the analysis because, firstly, asset ownership rather than consumption expenditure is considered a better estimate of the long-run economic status of the poor (Filmer and Pritchett 2001). Secondly, information collected on assets is believed to be more accurate than that on consumption, thereby reducing the likelihood of measurement error (Labonne, Biller, and Chase 2007). Following Filmer and Pritchett (2001), many other studies have utilized and recommended the use of principal component analysis for estimating household wealth (McKenzie 2005; Vyas and Kumaranayake 2006; Labonne, Biller, and Chase 2007). The constructed wealth index had a Pearson's correlation coefficient of 0.4289 for income and a Spearman's rank correlation coefficient of 0.5692 for income.

For a robustness check, the income of households was also used as an independent variable. The household income consists of the salaries and wages of all earning members of the household as well as income generated through rent, pensions, government schemes and other sources such as interests, dividends, etc. Summary statistics of all variables used in the different regression models are included in Appendix 8.3.

8.5 Household Water Consumption Profile

In Kathmandu, on average, the survey households have a per capita water consumption of 70 liters per capita per day (lcd) in the dry season and 85 lcd in the rainy season. According to the WHO (2011), for basic sufficiency, the minimum water requirement is deemed to be 50 lcd. In the dry season, the median amount is 41 lcd and 48 lcd in the rainy. This reflects that half of the households in the city do not have sufficient water to ensure that their basic hygiene and consumption requirements are met.

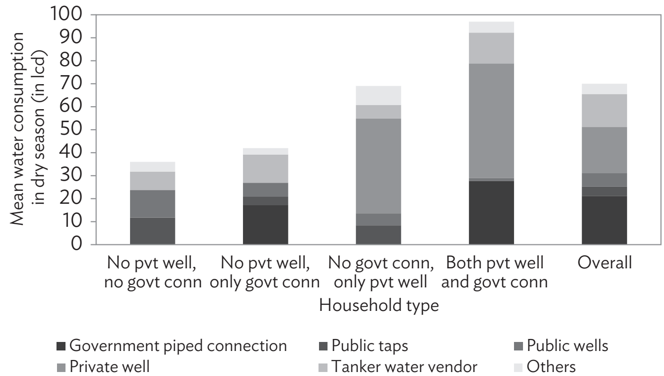
The survey asked households to list the different sources of water that they used for their needs (such as drinking, cooking, bathing, washing, cleaning, etc.), as well as how much water they obtained from each source. On average, households report having access to around four out of eight possible sources, but a majority (85%) report using around three of them. The data showed that even though 89% had access to the public piped water system, only 70% used water from it. This is possibly attributable to the current water supply system being both inadequate and irregular. On average, the households receive water for only 1.5 hours every 5 days. In terms of access, 21% have access to a public tap, 29% to a public well, and 55% to a private well. Only 8% of homes have access to a stone tap.

The data clearly reveal that most households do not rely on any single source of water to meet their needs. The main sources of household water are government piped water connections, private wells, and purchases from private tanker operators, with 30%, 29%, and 20% of household water consumption coming from these sources, respectively. All other sources combined, i.e., public wells, public taps, water from neighbors, bottled water, stone taps, and surface water, amount to less than 10% of the water obtained by households.

When the data are disaggregated by the type of source that is accessible to the household looking specifically at the government piped water connection and the private wells, we find that almost half of the sample households have access to both, about 40% only have access to a government connection, 5% have access only to a private well, and approximately 6% do not have access to either. In fact, those that fall in the first group tend to be significantly wealthier than the others with a monthly income that is twice as much as that of the other groups.

Water consumption differs significantly by the type of source a household has access to. Figure 8.1 shows the average proportion of water coming from different sources in each type of household's water

Figure 8.1: Water Consumption, by Quantity and Source, of Different Household Types



lcd = liters per capita per day.

Source: Authors.

consumption. Households without access to either a government connection or a private well use very little water, only 36 lcd in the dry season. On the other hand, households with access to both the sources consume more than twice that amount, around 97 lcd in the dry season.

8.6 Results

This section is divided into three subsections, each looking at the results related to the three key research questions.

8.6.1 Do Wealthier Households Have Greater Access to the Government Piped Water Network Than Poor Households?

Table 8.1 shows the marginal effects results of the probit regression that looks at the determinants of access to a government water connection. It shows that wealthier households consistently have greater access to government water connections as compared to poorer households, even while controlling for other mediating factors. Column 1 includes

Table 8.1: Factors Mediating Access to Government Piped Water Connection

Dependent variable - Access to government piped water connection (access=1, no access=0)

Variables	(1)	(2)	(3)	(4)	(5)	(6)
Wealth group: middle	0.073*** (0.014)	0.07*** (0.0143)	0.057*** (0.013)	0.043*** (0.013)		
Wealth group: rich	0.082*** (0.013)	0.08*** (0.012)	0.047*** (0.01)	0.036*** (0.01)		
Wealth index					0.034*** (0.011)	
Log of household income						0.051*** (0.007)
Ethnicity FE		Yes	Yes	Yes	Yes	Yes
Ward FE			Yes	Yes	Yes	Yes
Road FE			Yes	Yes	Yes	Yes
N	1,394	1,384	963	706	706	661
Pseudo R squared	0.044	0.064	0.217	0.201	0.199	0.256

Notes: Base group for wealth is poor. In Columns 4, 5 and 6, educational level and gender of the household head were controlled for. Robust standard errors in parentheses; * $p<0.1$, ** $p<0.05$, *** $p<0.01$.

Source: Authors.

only a measure of wealth and indicates that being a middle-income and rich household increases access to public utility water by 7.3% and 8.2%, respectively, when compared to the poorest 20%. Column 2 includes ethnicity into the model, and people belonging to "other *janjatis*" or indigenous ethnic groups have lower access to piped water when compared to Newars, the ethnic group with the highest score on the human development index as per the UNDP Nepal Human Development Report 2014 (Table A8.5). Even with this inclusion, wealth plays a significant role in determining access. Column 3 shows that this general pattern persists when dummies of location of residence and the type of road closest to the household are included, with the wealthier households having a greater chance of having access to the government network. The explanatory power of this model is also much higher than the previous model. Column 4 shows the results of the complete model, which includes education levels and gender of the household head. There is a significant negative predicted effect on access if the household is from the poor wealth category. Ethnic and ward-level differences remain and living near a pitch road increases access to piped connected as opposed to living near a dirt road (Table A8.5). While the education of the household head does not make a difference, it is found that if the household head is female, then there is a negative effect on access (Table A8.5).

Three tests of fitness were conducted on the model. First was the Hosmer-Lemeshow goodness-of-fit test, which indicated that the complete model has been specified correctly, since the chi square value was 196.93 with an associated p-value of 0.16. The Pregibon's link test also supported that the predictor variables have been specified correctly. Third, the Wald test results also implied that the selected explanatory variables together affect the outcome variable in a statistically significant manner.

8.6.2 Does the Quantity of Water Delivered through the Government Piped Water Supply System Differ between Poor and Nonpoor Households?

Table 8.2 shows the OLS regression results that examine the factors that could mediate the quantity of water in liters collected per day in the dry season from the government piped water connection. This has also been estimated for rainy season water for which the results can be found in Table A8.6b). The numbers of observations are reduced in this analysis because they take into account only those households that received water from their piped connection. The results for both the dry and rainy seasons consistently show that poorer households connected to the government piped network obtain less water per day than rich households in both seasons. However, the gap between the quantities of water collected by the poor and nonpoor is greater in the rainy season, possibly because the greater availability of water benefits the wealthy in a disproportionately positive way.

Table 8.2: Factors Affecting Quantity of Water Obtained by Households in the Dry Season
(liters per day)

Dependent variable - Log of quantity of water collected from the piped water connection by the household in the dry season

Variables	(1)	(2)	(3)	(4)	(5)	(6)
Wealth group: middle	0.169* (0.0885)	0.138 (0.0879)	0.159** (0.0781)	0.245*** (0.0844)		
Wealth group: rich	0.396*** (0.121)	0.326*** (0.123)	0.316*** (0.110)	0.387*** (0.116)		
Wealth index					0.0224*** (0.007)	
Log of household income						0.118** (0.0487)
Household size	−0.002 (0.0207)	0.002 (0.0208)	0.005 (0.0182)	−0.011 (0.0178)	0.017 (0.0147)	−0.002 (0.0164)
Own electric pump and generator				0.270* (0.147)	0.361** (0.144)	0.328** (0.136)
Own electric pump only				0.118 (0.150)	0.129 (0.151)	0.0937 (0.143)
Service: medium				−0.539*** (0.106)	−0.509*** (0.108)	−0.502*** (0.106)
Service: poor				−0.710*** (0.109)	−0.667*** (0.109)	−0.676*** (0.110)
Ethnicity FE		Yes	Yes	Yes	Yes	Yes
Ward FE			Yes	Yes	Yes	Yes
Constant	4.070*** (0.103)	3.943*** (0.106)	4.525*** (0.148)	4.536*** (0.449)	4.524*** (0.448)	3.382*** (0.617)
N	940	940	940	668	668	669
R-squared	0.016	0.045	0.333	0.531	0.524	0.519

Notes: Base group for wealth is poor and for service is good. In Columns 4, 5 and 6, control of service hours was included. Robust standard errors in parentheses; * $p<0.1$, ** $p<0.05$, *** $p<0.01$.

Source: Authors.

In Column 1 of Table 8.2, it can be seen that belonging to the middle and rich wealth categories leads to the household obtaining 17% and 40% more water per day, respectively, than the poor households. Household size has no significant effect on water collection levels. Column 2 controls for ethnicities and it shows that some (Brahmans, Dalits and other *janjatis*) obtain more water than Newars (see Table A8.6a), which shows that there is no inequity based on ethnic differences. Column 3 adds the location of residence and reveals that households in Lalitpur, Bhaktapur and Kirtipur tend to collect more water from the public utility connection than those in Kathmandu. The effects of wealth remain, with middle wealth households obtaining 16% more water and the rich 31.5% more. Column 4 controls for service quality (number of days between water supply and the number of hours for which the water is supplied on the day it comes), as well as whether households have an electric pump and generator that can be used to extract greater water during time of supply.

Looking at Column 4 of Table 8.2 shows that the explanatory power of this model is substantially higher than the previous ones. Further, poorer households still obtain significantly less water from the government connection even when factors such as service quality, location of residence, ethnicity and ownership of pumps and generators are accounted for. While there are some ward-level effects, the quantity of water obtained per day for households with poorer service is significantly reduced. Households receiving medium-level service get 53.9% less water than those with good service, and those with poor service get 71% less per day. The effect of owning both a pump and generator is also significant. Households with both get 27% more water. Household size is not significant in any of the models.

To ensure that the model has been specified correctly, the Ramsey RESET (Regression specification-error test for omitted variables) was conducted (Ramsey 1969). The result of the test (f-statistic of 1.56 with an associated p-value of 0.2) confirmed that there were no omitted variables in the model. Additionally, Pregibon's link test was also conducted, the results of which also confirmed that the model is specified correctly. Lastly, the Wald test confirmed that the independent variables collectively affect the dependent variable in a statistically significant manner.

8.6.3 Does the Quality of Water Delivered to Households Differ between the Poor and Nonpoor Households?

Table 8.3 shows the maximum likelihood estimates of the risk perception model in the dry and rainy season in columns 1 and 2, respectively. The reported results in the table are the marginal effects. Across both the seasons, it is seen that wealth does not have a statistically significant influence on the perceived health risk of government piped water. There is also a significant positive effect of living near a pitch road and a significant negative effect of living near a stone/brick road (as compared to a dirt road) on the perceived quality of piped water (Table A8.7). It is possible that the latter correlates with the older parts of Kathmandu city and perhaps the older infrastructure that affects the aesthetic properties, which are important factors in explaining perceived risk. Piped water that is perceived to be dirty or having a bad taste, as expected, enhances a household's belief that it has a higher health risk. Education level of the household head does not have significant effect.

Both the likelihood ratio and the Wald test indicate that the overall model is well specified and that the independent variables influence the dependent variable in a statistically significant way.

Table 8.3: Factors Affecting Perceived Quality (Health Risk) of Water from the Piped Water Network in Both the Dry and Rainy Season

Dependent variable - Perceived health risk of water in different seasons (1=no risk, 2=little risk, 3=some risk, 4=serious risk)

Variables	Dry Season (1)	Rainy Season (2)
Wealth group: middle	−0.00330 (0.0931)	0.0709 (0.0956)
Wealth group: rich	−0.0236 (0.112)	−0.0855 (0.115)
Perceived color of water (ranges from 1 for very clean to 4 for very dirty)	0.294*** (0.0886)	0.667*** (0.0933)
Perceived taste of water (ranges from 1 for excellent to 4 for poor)	0.538*** (0.0737)	0.583*** (0.0751)
Ethnicity FE	Yes	Yes
Ward FE	Yes	Yes
Road FE	Yes	Yes
N	820	827
Pseudo R-squared	0.199	0.251

Notes: Base group for wealth is poor. Educational level of the household head was controlled for in Columns 1 and 2. Robust standard errors in parentheses; * p<0.1, ** p<0.05, *** p<0.01.

Source: Authors.

To ensure the robustness of these results, several checks were conducted, such as testing the results of access to water with an alternative outcome variable that measures household use of water and using the Heckman Selection method to check for selection bias. The results and explanations of these can be found in Appendix 8.4.

8.7 Discussion and Conclusion

The results of the analysis indicate that there is marginalization of the poor from the government piped water network. This is because, first, poorer households had significantly less access than richer households, despite accounting for various other factors, such as location of residence or roads. This is an important result because we find that a difference exists even though 89% of the sample has access to a piped water connection. Hence, it is households from the poorest wealth group that predominantly make up the unconnected 11%. In fact, the inequity is more pronounced when one looks at whether the household uses water from the government piped network connection. We find being from a wealthy household increases your chance of using water from the government connection by 15%, whereas in terms of access it amounts to only approximately 4%. This supports the argument that looking at mere physical access tells us little about the policy outcome and minimizes the inequity that exists in real access to water.

In addition to this, for the households that did have access, the results found that poorer households consumed less water per day in both seasons than wealthier households. This reflects significant distributional inequity in Kathmandu. Perceived quality of water did not differ across wealth groups, possibly because of the centralized process of delivery through specific water treatment plants. If the water quality is poor, all households, rich and poor, are likely to be affected similarly through the areas serviced by the same pipeline.

In terms of access, all other ethnicities had lower access than Newars, which is logical because historically Kathmandu was known as a Newar settlement, and land ownership is a key determinant of household water connection. The government provides access to the piped network only to those who have a land ownership certificate. Today, Newars constitute only 32% of the population (followed by Brahmans and Chhetris who constitute 22% and 16% of the population, respectively) due to intense migration, even though they are the single largest ethnic group in the city (Subedi 2010). Geographically, the Newars show a spatial pattern of concentration in the older sections of the city. As a community, they also rank the highest in terms of human development indicators.

Therefore, given that they have lived in the city for the longest and also occupy a privileged status, it seems inevitable that they would have the highest access to public utility water. While the education level did not affect access to piped water, the gender of the household head did (at 0.1 level of significance). This shows that there is gender-differentiated access, which may be due to various social or cultural barriers women face in going out and getting a connection. Income was also found to be positively related with access and amount of water they obtained from the piped network, if households were connected.

A report looking at corruption in infrastructure provision and service delivery in Nepal (Shreshtha 2007) found that consumers often pay bribes to water supply personnel in order to direct more flow into their area by manipulating the valves. This could explain why wealthier households have a greater water collection volume, even though municipalities are controlled for.

Further, the amount of water obtained by the households in the two different seasons from the government connection revealed that there was no effect of household size. This is because the water from an existing government connection is the easiest to obtain as it is available at the point-of-residence and is cheaper than the alternatives. For comparison, the public utility charges NRs100 ($0.93) for a minimum consumption of 10,000 liters (KUKL 2014) for domestic use. On the other hand, survey results show that a 5,000-liter tanker truck, on average, costs households NRs1,300 ($12.14). Therefore, households are likely to maximize the collection of water received from their piped connection. Furthermore, since supply is intermittent, households are likely to draw the maximum quantity they can during the hours in which the water is supplied (Kumar 1998; Bradley and Mediwake 2002). This would be unaffected by the number of household members because, as mentioned, the total amount of water received through the government connection tends to be insufficient to meet household needs, resulting in reliance on multiple supplementary water sources.

The reliability of service, as expected, affected how much water households get from the connection, though, surprisingly, the number of hours did not have a significant relationship. This could be because its effect was captured in other variables, such as ward number or the level of service. As is evident from the results, households (usually wealthier ones) tended to use electric pumps and electricity back-up generators to extract greater volumes of water when available, leaving even less for those who cannot afford to do so. However, despite accounting for all these factors that influenced collection, the wealth of a household consistently affected access to, and amount of, piped water collected in a statistically significant manner.

Therefore, it is evident that there is distributional inequity in both access and flow between poor and nonpoor households in Kathmandu. The results of this study highlight the inequities that get masked when looking merely at policy outputs, in this case, "a household connection to water". While the difference between poor and rich households' access to the connection is only about 3.6%, the difference in the quantity of water received is about 40%. Evidently, while a subsidized public utility water supply system is intended to support poor households, the network in Kathmandu strongly favors the wealthy. The provision of adequate water positively affects the economic wellbeing, health, and hygiene, as well as educational levels, of a household, all of which are inextricably linked to poverty. Given that Nepal is among the poorest countries in the world and that the provision of water is already at the bare minimum, this gross disparity needs to be addressed in a comprehensive and inclusive manner. A crucial policy implication of this is the need for an integrated plan that considers the long-term technical, managerial, and financial sustainability of the utility. Merely extending pipelines to households will not result in improved outcomes, unless the service provision is also improved. Thus, an increased focus on bridging the service gap and not just the access gap is important.

While it may take time to address these issues at an infrastructural level, short- and medium-term strategies need to be formulated so that the needs of all households, not just the wealthy, are met in an affordable, adequate, and safe manner. A short-to-medium-term solution includes the acceptance of differentiated service levels for different parts of the city. This implies that, for those areas that are currently underserved or completely disconnected from the piped network system, the government should allow for regulated water vendors to supply those areas. However, in the longer term, where the current piped network exists, the best practice is to develop district metered areas, that is, hydraulically isolated sub-areas of a distribution network comprised of anywhere between 500–3,000 connections, where both inflow and outflow is measured. Complete distribution networks can be covered in such a manner. Through flow monitoring of district metered areas, both production and losses can be estimated accurately and thereby accurate leak detection can be undertaken. When a supply system is divided into such smaller, more manageable areas, the utility can better target its non-revenue water reduction activities, pinpoint water quality issues, and manage the overall system pressure better to allow for round-the-clock water supply through the network. In a city like Kathmandu, where non-revenue water losses are anywhere between 40%–60% (KUKL 2014), this can enhance the service quality as well as the quantity of water supplied to the households. Also, the tariffs can be slowly increased in a phased manner, with improved service delivery to aid cost recovery and financial sustainability of the utility.

A limitation of the sample used in this study is that it is based on the one selected in 2001. While the sample accurately represented the spatial representation of households in the Kathmandu Valley in 2001, the same does not hold true for 2014. Overall, the sample of households in 2014 is wealthier than the average household in Kathmandu. Additionally, the sample is primarily comprised of homeowners; therefore, we find that most have access. While wealthier households have 3.6%–4.3% greater access than the poor, the difference is not very large. This difference implies that the inequity levels that have been revealed through this study are most likely understated. This is because they do not account for the households that have migrated in the time between the two surveys and are probably living in the newer, peri-urban areas with lower incomes. This underscores the need to urgently address the issues relating to household water security.

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Appendix 8.1: Data Collection Details

For the 2014 survey, if the original household could not be located, a nearby household in the same cluster as in 2001 was selected for the interview. When the household head from 2001 was missing, the present head or a responsible member of the house was interviewed instead. In total, 927 of the 1,500 households of the 2001 survey were located and re-interviewed.[2] Thus, in the 2014 survey, there are 573 replacement households. Since the sampling procedure followed for 2001 was extremely robust, it has been assumed that the 2014 re-survey data can be validly used for a cross-sectional analysis.

The 2014 survey was a modified version of the 2001 survey instrument and consisted of 12 sections that looked at household demographic and socio-economic characteristics, access and usage of various water sources, engagement with the water vendors, water use and treatment practices, household water infrastructure, and household sanitation service, as well as household knowledge, attitudes, and preferences toward different types of water tariff structures. Since the data have been drawn largely from the modified sections of the survey, a panel analysis was not undertaken.

A total of 19 experienced field surveyors were hired and trained for field data collection for survey. The team was divided into groups of 3–4 members with an assigned team leader who checked the forms for data consistency at the end of each working day. A 9-day training was conducted for the field team that focused on informed consent and ethical issues, rapport building, overall interview and survey methodology, skipping patterns, intent of each question, sources of data collection errors and how to minimize them, and managing and editing of the completed questionnaires. A pre-test of 50 questionnaires was carried out and the issues were identified and incorporated into the final questionnaire. A professional translator translated the survey instrument into Nepali. Finally, a blind double entry of data was used to minimize errors.

[2] Overall, 60% of the replacements were due to the enumerators being unable to find the house (as there were no GPS locations taken in 2001), 12% because the house had been sold, and 7.5% because the house had been rented out.

Appendix 8.2: Empirical and Analytical Strategy

From the theoretical discussion on horizontal equity in the public utility system, three clear outcome variables emerged (i.e., access to government piped water network, volume of household water collection from and quality of piped water). For a robustness check, all three regressions were also run with the log of household income and wealth as a continuous variable. In this section, the empirical and analytical strategy is detailed, which explains the choice of regression models and variables used in the study.

Access to Piped Water Network

To measure access, a probit regression model was used since it is a binary variable, where 1 implies that households have access to government piped water and 0 implies that they do not. The general model is stated below.

$$Pr(Y_i=1|X_{1i}) = \Phi(\beta_1 X_{1i}+e_i) \quad (1)$$

where the dependent variable Y_i is a binary variable for whether households have access to piped water or not, Φ is the cumulative standard normal distribution function, and X_{1i} is a set of socioeconomic variables including wealth group, ethnicity, ward where the household resides, closest road to the household, education level, and gender of the household head.

Wealth is the wealth group index based on the assets of the households, where 1 represents the richest 20%, 2 represents the middle 40%, and 3 the poorest 20%.

Ethnicity is the ethnic identity of the household. 1 is the Newars, 2 are the Brahmans, 3 are indigenous groups, 4 are Madhesis, 5 are Dalits, and 6 are Muslims.

Ward is the ward number within which the household resides. There are 35 in Kathmandu.

Road is the type of road closest to the household, where 1 represents a dirt road, 2 is a stone/brick road, and 3 is a paved road.

Education is the level of educational achievement of the household head, which was categorized as 0 for no education, 1 for primary and non-formal education, and 2 for secondary education and higher.

Gender is the gender of the household head with 1 representing male and 0, female.

The dependent variable was measured based on the survey question that asks households whether they had access to a government piped water network. Therefore, access could be ascertained for each household. Since the aim of the chapter was to determine whether access is equitable across households of differing economic status, the independent variable of interest was the wealth of the household, which could be determined through the reported income, expenditure, or assets in the households. In this study, an asset-based wealth index was used. The construction of this variable is described in further detail in section 7. To isolate the effect of wealth, it was essential to control for all the other factors that might affect households' access to public utility water. These were selected based on factors that were identified through the review of the literature. To account for the locational or physical factors, variables of the ward number that the household resided in and the type of road that was closest to the home were included. Both were indicative of the geographical factors, as well as certain socio-economic ones, as it is likely that poorer households lived near dirt roads, whereas wealthier ones chose to live near paved roads. Demographic factors such as ethnicity, which is a key form of self-identification in Nepal (Subedi 2010), and education level of the household head were also included. It is expected that, in controlling for the ward, any differences in the institutional factors and other neighborhood effects that may influence the way water is supplied to the area have been accounted for. If inequity exists, then it is expected that being in lower wealth groups would negatively affect the household in having access to the government piped water network.

Collection of Water from the Piped Network System

In order to examine the second outcome variable, an ordinary least squares model was utilized. The amount of water collected is measured for only those who have access to the government piped network. The log of the dependent variable was taken for easier interpretation of results. Therefore, the general model used was as follows:

$$\begin{gathered} Log\,(Collection_i) = + \,Wealth_i + Ethnicity_i + Ward_i + \\ Owner\ of\ electric\ pump_i + Owner\ of\ electric\ pump\ and \\ generator_i + Service_i + Hours\ of\ Service_i + Household\ Size_i + U_i \end{gathered} \tag{2}$$

where $Collection_i$ refers to the quantity of water (in liters per day) obtained by the household in the dry and wet season from the public water connection.

Owner of electric pump$_i$ refers to whether the household owns an electric pump. It is a dummy variable where 1 represents ownership and 0 does not.

Owner of electric pump and generator$_i$ refers to whether the household owns both an electric pump and a generator/inverter for use when there is no electricity. It is a dummy variable where 1 represents ownership of both and 0 does not.

Service$_i$ refers to the quality of service depending on the number of days between when water is supplied to the household. Service is 1 when water supply comes every day or within a 2-day period, reflecting good service by Kathmandu standards. Service is 2 (medium service) when water comes between 2 to 5 days. Service equals to 3 when it is poor, i.e., there is a gap greater than 5 days in between water supply service.

Hours of service$_i$ refers to the number of hours water is supplied during the water supply period. It equals 1 if water is supplied for greater than 6 hours, 2 if water supplied is between 1 to 6 hours, and 3 if it is less than one hour.

Household size$_i$ refers to the number of family members residing in the household.

All remaining variables were the same as previously mentioned.

To measure the dependent variable in this model, in the survey, households were asked how many liters of water were collected per day in both the dry and rainy season (specifically, how many times a week and how much each time). While a per capita measure is more commonly used for water consumption, this is not used in the present analysis because of the water scarcity situation in Kathmandu. Given the overall inadequacy of the public water supply, households would maximize collection from piped water connections regardless of the number of people in the home because it is the most convenient and cheap source (~$1/10,000 liters). A per capita measure would be appropriate if water consumption from all possible water sources were being considered here. Household size is, however, included in the regression to assess this assumption that the number of members in a house would not affect consumption levels.

To analyze whether the distribution of public water supply varied across households, the independent variable chosen was an indicator of wealth and ethnic identity as well as ward of residence were selected as control variables (for reasons mentioned previously). Since quantity collected would be affected by the service itself, the number of hours that water was supplied for, as well as how often the water came in the pipeline, was also included in the regression model. The greater the availability, the greater would be the collection. The survey asked, "How many days are there between when you get water from your government water connection?" and "At these times, how many hours do you get it for?" Using these, it was possible to estimate what in the context of Kathmandu reflected good, poor, and medium service by looking at the distribution of the responses. Another aspect to consider was that, in Kathmandu, households often installed electric pumps that were used for water and stored in overhead tanks when water came through the government supply. This allows the household to use the stored water over the rest of the day. If water is not pumped and stored, then running water will cease after the few hours of delivery time. Similar to water, electricity was also supplied intermittently, and daily load shedding was common in different parts of the city (based on a pre-announced schedule). Therefore, households with an electric pump or those with both a generator (or inverter) for use when there was no electricity in the house and an electric pump were likely to consume greater water and had to be accounted for. Lastly, another aspect that would affect quantity of water collected was the reliability of service that could be determined by the number of days between them getting water supply.

Quality of Water

Quality of water is an important criterion in assessing a supply system because it is closely related with health outcomes. While this study did not empirically test household tap water samples for quality measures, it did ask the household's perception of the health risk posed by the water in two different seasons, which was considered a proxy for the perceived quality. Therefore, in order to assess whether the perception of quality of piped water systematically varied across wealth groups, an ordered probit model was used that included the explanatory variables of wealth, ward number within which the household resides, type of road closest to home, education of the household head, as well as taste and color of the water (both of which are considered to be exogenous). These explanatory variables were used to predict the probabilities of households perceiving different levels of health risk from the piped water network as shown below.

$$y_i^* = \beta' x_i + \varepsilon_i \qquad (3)$$

where y_i^* is a latent measure of health risk perceptions of households toward the government piped water network; x_i is a vector of the explanatory variables; β' is a vector of the parameters to be estimated, and ε_i is the error term that is assumed to be normally distributed. Since it is not possible to observe y_i^* one can only observe the categories of responses as follows:

$$y_i = \begin{cases} 1 \Rightarrow \textit{no risk perceived if } -\infty < y_i^* < \mu_1 \\ 2 \Rightarrow \textit{little risk perceived if } \mu_1 < y_i^* < \mu_2 \\ 3 \Rightarrow \textit{some risk perceived if } \mu_2 < y_i^* < \mu_3 \\ 4 \Rightarrow \textit{serious risk perceived if } \mu_4 < y_i^* < \infty \end{cases}$$

The thresholds μ indicate an array of the normal distribution related to definite values of the explanatory variables.

For the third dependent variable in the survey, households were asked, "How would you judge the health risk of water from the piped water connection?" for both seasons. The responses were categorized as "no risk", "little risk", "some risk", "serious risk" or "don't know". These responses were used as indicators of perceived quality of the water they received from the government utility. The household that said they "don't know" were excluded from the analysis.[3] Similar to the previous regression models, explanatory variables of wealth group, ethnicity, ward number where the household lives and roads were included. However, in addition, aesthetic characteristics of water such as taste and color were also included because they were likely to influence risk perception. In the survey, households were asked, "(Before any treatment your household may do), how would you judge the taste of water from each source?" and "(Before any treatment your household may do), in the rainy season, how would you judge the color of water from each source?", for both seasons separately. As responses for the questions, households could choose between "excellent", "good", "fair/normal", "poor", and "don't know" and "very clean", "clean", "dirty", "very dirty", and "don't know", respectively. Water quality attributes were assumed to be exogenous as the expectation was that a poor taste and dirty water would induce a higher perceived risk and not vice versa. Education of the household head was also included because a better-educated household head was expected to be more aware of water quality and related health risk. Since, in this study, the "true" quality of water was not observed, one could not test whether better-educated households had better judgements about water quality than less-educated households.

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[3] Only 100 households in the sample responded "don't know".

Appendix 8.3: Data Description

Three dependent variables were used in the analysis: a dummy for whether a household can access a government piped water connection, the quantity of water obtained by the household from this connection (in liters per day, if they have access), and the perceived water quality of the piped water (ranging from low to serious health risk perception).

The explanatory variable of interest was the wealth group, and the control variables consisted of the location of residence (ward level) and the type of road that was closest to the household (dirt road, narrow brick road or paved road), ethnicity (six major categories as reported in the UNDP Nepal Human Development Report 2014), education of the household head (0 for no education, 1 for primary and non-formal education and 2 for secondary education and higher), gender of the household head, service in terms of the number of days between government water supply and service hours in terms of the hours for which water was supplied by the government when it came, a dummy for whether the household owned an electric pump and a generator for use when there was no electricity and perceived taste (1 for excellent, 2 for good, 3 for fair/normal, 4 for poor), and color of piped water (1 for very clean, 2 for clean, 3 for dirty, 4 for very dirty). The two service quality variables were categorized into good, medium, and poor depending on the distribution of the responses. In countries with 24-hour service, anything less than that would be considered poor. But, given the reality of the Kathmandu water supply service, getting water every 2 days was considered good, medium was every 2–5 days, and poor was every 6 or more days. For service hours, it was good if water was supplied for greater than 6 hours, medium if water was supplied between 1 to 6 hours, and poor if it was less than 1 hour.

These service variables are included to see whether service quality affects collection, with the question being, despite the supply within communities being the same in terms of days or hours, do the wealthier households (through some form of elite capture such as bribing or personal contacts) still manage to gain greater amounts of water. Summary statistics of all variables used in the different regression models are included in Table A8.1, and distribution of key control variables such as ethnicity, road nearest to the household, gender, and education of the household head is shown in Table A8.2.

Table A8.1: Description of the Variables Used in the Regression Analysis

Variable Name	Variable Description	Obs.	Mean	Std. Dev.	Min.	Max.
Access to government water connection	Dummy for whether the household can access a government piped water connection	1,460	0.89	0.31	0	1
Quantity of water in the dry season	Quantity of water (in liters per day) obtained by the household in the dry season from the piped water connection	983	125.62	182.53	1	3,000
Quantity of water in the rainy season	Quantity of water (in liters per day) obtained by the household in the rainy season from the piped water connection	1,041	239.62	328.41	2.67	3,500
Quality of water in the dry season	Perceived health risk from piped water connection by the household in the dry season (1-no risk perceived, 2-little risk perceived, 3-some risk perceived, 4-serious risk perceived)	1,227	3	1	1	4
Quality of water in the rainy season	Perceived health risk from piped water connection by the household in the dry season (1-no risk perceived, 2-little risk perceived, 3-some risk perceived, 4-serious risk perceived)	1,237	3	1	1	4
Wealth index	Wealth index as described in Section 7.	1,394	0.002	4.53	−1.09	75.27
Wealth groups	Wealth groups (1=poorest 40%, 2=middle 50%, 3=richest 20%)	1,394	2.2	0.75	1	3
Log of household income	Log of household income in millions	1,492	11.2	1.47	6.21	17.73
Owner of electric pump	Dummy for whether the household owns only an electric pump, no generator (1=owns, 0=does not own)	1,500	0.54	0.5	0	1
Owner of electric pump and generator	Dummy for whether the household owns both an electric pump and a generator (1=owns, 0=does not own)	1,500	0.24	0.43	0	1

continued on next page

Table A8.1 *continued*

Variable Name	Variable Description	Obs.	Mean	Std. Dev.	Min.	Max.
Service	Service quality in terms of number of days between water supply availability (1=good, 2=medium, 3=poor)	1,500	2.43	0.77	1	3
Hours of service	Service quality in terms of numbers of hours water is supplied for each time (1=good, 2=medium, 3=poor)	1,199	1.84	0.77	1	3
Perceived Color - rainy season	Perceived color of piped water in the rainy season (1 for very clean, 2 for clean, 3 for dirty, 4 for very dirty)	1,247	2	1	1	4
Perceived Color - dry season	Perceived color of piped water in the dry season (1 for very clean, 2 for clean, 3 for dirty, 4 for very dirty)	1,235	2	1	1	4
Perceived Taste - rainy season	Perceived taste of piped water by the household in rainy season (1 for excellent, 2 for good, 3 for fair/normal, 4 for poor)	1,121	3	1	1	4
Perceived Taste - dry season	Perceived taste of piped water by the household in the dry season (1 for excellent, 2 for good, 3 for fair/normal, 4 for poor)	1,110	3	1	1	4

Notes: Distribution of variables such as ethnicity, road, education and gender of household head can be found in Appendix 8.1.

Source: Authors.

Table A8.2: Distribution of Other Control Variables Used

Variable	Details	Freq	%
Ethnicity	Newar	972	65.06
	Brahman	369	24.70
	Janjati	122	8.17
	Madhesi others	3	0.20
	Dalit	13	0.87
	Muslim	15	1.00
	Total	**1,494**	
Road	Dirt road	272	18.63
	Pitch Road	454	31.10
	Stone/Brick	734	50.27
	Total	**1,460**	
Education of household head	No education	33	2.94
	Primary or non-formal	458	40.82
	Secondary and above	631	56.24
	Total	**1,122**	
Gender of household head	Male	1,169	78.25
	Female	325	21.75
	Total	**1,494**	

Source: Authors.

Appendix 8.4: Robustness Checks

In order to check the robustness of the results, the complete probit model on access (equation 1) was run with the dependent variable being a dummy of whether households use water from a government connection or not (because, in developing cities, having a point of connection, i.e., access, does not necessarily imply that it is functional which relates to actual usage). The results as seen in Table A8.3 show that the significance and direction of all the variables were the same, though the magnitudes of the coefficients differed. Here, too, wealthier households were more likely to use water from the government connection.

Table A8.3: Probit Regression Results of Whether Households Use Water from Government Water Connections

Dependent variable - Use of government piped water connection (use=1, do not use=0)

Variables	(1)
Wealth group: middle	0.155*** (0.03)
Wealth group: rich	0.152*** (0.03)
Ethnicity FE	Yes
Ward FE	Yes
Road FE	Yes
N	1,011
Pseudo R squared	0.111

Notes: Base group for wealth is poor. Education level and gender of the household head were controlled for. Robust standard errors in parentheses; * $p<0.1$, ** $p<0.05$, *** $p<0.01$.

Source: Authors.

Further, to ensure that there was no selection bias in the second regression on quantity of water collected by households from the private water connection (since only households with access are selected), the results were cross-checked with results of a Heckman Selection two-step procedure. The idea of the two-step procedure is as follows:

$$Y_1 = X_1\beta_1 + u_1$$
$$Y_2 = 1[X_2\beta_2 + u_2 > 0]$$

The first equation in the above system is the collection equation for households who have access to the government piped network system. It takes the same specification as equation 2. The second equation is a probit regression, taking the same specification as equation 1, that takes value 1 if a household has access to the government piped network, and 0 otherwise. We would only observe values for Y_1 if $Y_2 = 1$. In particular, education and gender of the household head and the type of road closest to the household are used as excluded instruments in the selection model. These variables, as explained in equation 1, are likely to affect access, but do not directly affect the amount of water that is likely to be obtained through the connection that already exists. The results, as reported in Table A8.4, revealed only marginal differences between the coefficients of the two models. The significance and direction of the results were the same. This implies that the OLS results are robust.

Table A8.4: Comparison of Coefficients of Heckman Selection Model and OLS results

Dependent variable - Log of quantity of water collected from the piped water connection by the household in the dry season (in liters per day)

Variables	Heckman Selection Model	OLS
Wealth group: middle	0.231** –0.108	0.245*** –0.0844
Wealth group: rich	0.399*** –0.134	0.387*** –0.116
Household size	–0.0212 (0.0180)	–0.0108 (0.0178)
Own electric pump and generator	0.390*** (0.150)	0.270* (0.147)
Own electric pump only	0.199 (0.155)	0.118 (0.150)
Service: medium	–0.548*** (0.105)	–0.539*** (0.106)
Service: poor	–0.688*** (0.112)	–0.710*** (0.109)
Ethnicity FE	Yes	Yes
Ward FE	Yes	Yes
Constant	4.485*** (0.373)	4.536*** (0.449)
N	868	668

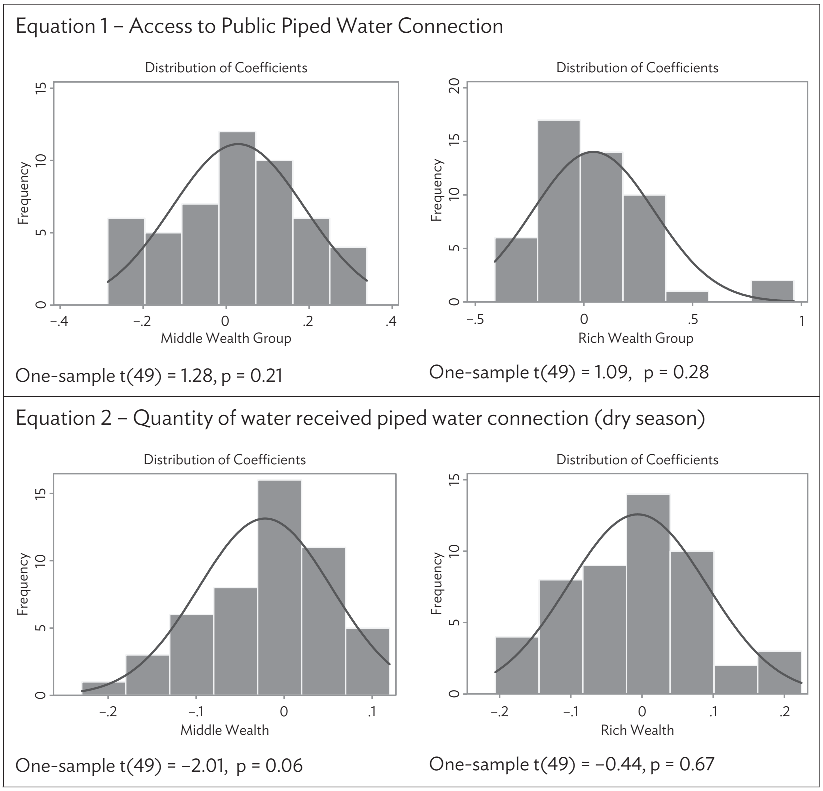
OLS = ordinary least squares.

Notes: Base group for wealth is poor and for service is good. Controls of service hours was included. Robust standard errors in parentheses; * p<0.1, ** p<0.05, *** p<0.01

Source: Authors.

Lastly, to ensure that the wealth effects being seen in the results are robust, equations 1 and 2 were re-run 50 times with the wealth groups randomized. The results as seen in Figure A8.1 showed that the mean of the distribution of the coefficients were not different from zero in a statistically significant manner. Therefore, we can infer that the results seen are robust.

Figure A8.1: Robustness Check for Wealth Coefficient



Appendix 8.5: Complete Tables

Table A8.5: Marginal Effects Results of the Probit Regression for Factors Mediating Access to Government Piped Water Connection

Dependent variable - Access to government piped water connection (access=1, no access=0)

Variables	(1)	(2)	(3)	(4)	(5)	(6)
Wealth group: poor	. (.)	. (.)	. (.)	. (.)		
Wealth group: middle	0.073*** (0.014)	0.07*** (0.0143)	0.057*** (0.013)	0.043*** (0.013)		
Wealth group: rich	0.082*** (0.013)	0.08*** (0.012)	0.047*** (0.009)	0.035*** (0.01)		
Wealth index					0.034*** (0.007)	
Log of household income						0.051*** (0.008)
Ethnicity1: Newar		. (.)	. (.)	. (.)	. (.)	. (.)
Ethnicity2: Brahman		−0.004 (0.018)	0.0179 (0.014)	0.0143 (0.0135)	0.006 (0.007)	0.03* (0.15)
Ethnicity3: Other janjati		−0.14*** (0.052)	−0.11*** (0.047)	−0.116*** (0.06)	−0.068*** (0.042)	−0.14*** (0.07)
Road1: dirt			. (.)	. (.)	. (.)	. (.)
Road2: pitch			0.03* (0.013)	0.025* 0.019	0.012 (0.008)	0.046*** (0.017)
Road3: stone/brick			0.18 (0.014)	0.001 (0.015)	−0.001 (0.008)	0.02 (0.017)
Education0: no education				. (.)	. (.)	. (.)
Education1: primary and non-formal				0.028 (0.029)	0.016 (0.016)	0.04 (0.031)
Education2: secondary and above				0.037 (0.035)	0.021 (0.02)	0.048 (0.036)
Gender of household head				−0.023* (0.01)	−0.012 (0.006)	−0.03** (0.013)
Ward FE			Yes	Yes	Yes	Yes
N	1394	1384	963	706	706	661
Pseudo R squared	0.044	0.064	0.217	0.201	0.1989	0.257

Note: Robust standard errors in parentheses; * p<0.1, ** p<0.05, *** p<0.01.

Source: Authors.

Table A8.6a: OLS Regression Results for Factors Affecting Quantity of Water Obtained by Households in the Dry Season from the Government Piped Water Connection

(liters per day)

Dependent variable – Log of quantity of water collected from the piped water connection by the household in the dry season (in liters per day)

Variables	(1)	(2)	(3)	(4)	(5)	(6)
Wealth group: poor	0 (.)	0 (.)	0 (.)	0 (.)		
Wealth group: middle	0.169* (0.089)	0.138 (0.088)	0.159** (0.0781)	0.245*** (0.0844)		
Wealth group: rich	0.396*** (0.121)	0.326*** (0.123)	0.316*** (0.110)	0.387*** (0.116)		
Wealth index					0.0224*** (0.00691)	
Log of household income						0.118** (0.0487)
Household size	−0.002 (0.021)	0.002 (0.021)	0.00490 (0.0182)	−0.0108 (0.0178)	0.0170 (0.0147)	−0.00189 (0.0164)
Ethnicity1: Newar		0 (.)	0 (.)	0 (.)	0 (.)	0 (.)
Ethnicity2: Brahman		0.337*** (0.089)	0.138 (0.0921)	0.176* (0.0942)	0.173* (0.0952)	0.141 (0.0942)
Ethnicity3: Other janjati		0.574*** (0.135)	0.386*** (0.130)	0.309*** (0.119)	0.319*** (0.119)	0.295** (0.118)
Ethnicity4: Dalit		1.240 (0.914)	1.029 (0.741)	1.225*** (0.251)	1.264*** (0.255)	1.315*** (0.250)
Ethnicity5: Madhesi Others		0.0787 (0.727)	0.106 (0.551)	−0.570 (0.565)	−0.622 (0.516)	−0.324 (0.461)
Ethnicity6: Muslim		0.494 (0.378)	−0.250 (0.437)	−0.00998 (0.354)	−0.0220 (0.376)	0.0444 (0.370)
Own electric pump and generator				0.270* (0.147)	0.361** (0.144)	0.328** (0.136)
Own electric pump only				0.118 (0.150)	0.129 (0.151)	0.0937 (0.143)
Service: good				0 (.)	0 (.)	0 (.)
Service: medium				−0.539*** (0.106)	−0.509*** (0.108)	−0.502*** (0.106)
Service: poor				−0.710*** (0.109)	−0.667*** (0.109)	−0.676*** (0.110)
Service hours: good				0 (.)	0 (.)	0 (.)

continued on next page

Table A8.6a *continued*

Variables	(1)	(2)	(3)	(4)	(5)	(6)
Service hours: medium				0.557 (0.409)	0.517 (0.411)	0.533 (0.357)
Service hours: poor				−0.298 (0.418)	−0.362 (0.419)	−0.347 (0.365)
Ward FE			Yes	Yes	Yes	Yes
Constant	4.070*** (0.103)	3.943*** (0.106)	4.525*** (0.148)	4.536*** (0.449)	4.524*** (0.448)	3.382*** (0.617)
N	940	940	940	668	668	669
R-squared	0.016	0.045	0.333	0.531	0.524	0.519

OLS = ordinary least squares.

Note: Robust standard errors in parentheses; * p<0.1, ** p<0.05, *** p<0.01.

Source: Authors.

Table A8.6b: OLS Regression Results for Factors Affecting Quantity of Water Obtained by Households in the Rainy Season from the Government Piped Water Connection

(liters per day)

Dependent variable - Log of quantity of water collected from the piped water connection by the household in the rainy season (in liters per day)

Variables	(1)	(2)	(3)	(4)	(5)	(6)
Wealth group: poor	0 (.)	0 (.)	0 (.)	0 (.)		
Wealth group: middle	0.269*** (0.0854)	0.235*** (0.0858)	0.218*** (0.0737)	0.299*** (0.0754)		
Wealth group: rich	0.540*** (0.122)	0.479*** (0.123)	0.449*** (0.110)	0.512*** (0.114)		
Wealth index					0.0118** (0.00470)	
Log of household income						0.0996** (0.0494)
Household size	−0.00543 (0.0201)	−0.000989 (0.0200)	−0.00757 (0.0178)	−0.0246 (0.0160)	0.0135 (0.0127)	−0.00188 (0.0141)
Ethnicity1: Newar		0 (.)	0 (.)	0 (.)	0 (.)	0 (.)
Ethnicity2: Brahman		0.283*** (0.0890)	0.0683 (0.0917)	0.0148 (0.0937)	0.0149 (0.0947)	−0.00807 (0.0936)
Ethnicity3: Other janjati		0.274** (0.115)	0.0782 (0.113)	−0.111 (0.118)	−0.0980 (0.121)	−0.130 (0.124)

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Table A8.6b *continued*

Variables	(1)	(2)	(3)	(4)	(5)	(6)
Ethnicity4: Dalit		1.427*** (0.497)	1.242** (0.492)	1.089*** (0.276)	1.129*** (0.291)	1.147*** (0.286)
Ethnicity5: Madhesi Others		−0.0358 (0.826)	0.0404 (0.660)	−0.940* (0.563)	−1.017** (0.498)	−0.552 (0.535)
Ethnicity6: Muslim		−0.0931 (0.384)	−0.849* (0.455)	−0.569 (0.357)	−0.585 (0.383)	−0.483 (0.384)
Own electric pump and generator				0.306*** (0.114)	0.439*** (0.115)	0.379*** (0.115)
Own electric pump only				0.177 (0.122)	0.206* (0.125)	0.167 (0.124)
Service: good				0 (.)	0 (.)	0 (.)
Service: medium				−0.398*** (0.103)	−0.369*** (0.105)	−0.345*** (0.104)
Service: poor				−0.683*** (0.108)	−0.638*** (0.109)	−0.633*** (0.111)
Service hours: good				0 (.)	0 (.)	0 (.)
Service hours: medium				0.167 (0.362)	0.124 (0.347)	0.114 (0.311)
Service hours: poor				−0.918** (0.369)	−1.001*** (0.355)	−1.018*** (0.319)
Ward FE			Yes	Yes	Yes	Yes
Constant	4.647*** (0.0972)	4.557*** (0.0978)	4.882*** (0.161)	5.351*** (0.391)	5.299*** (0.374)	4.414*** (0.601)
N	997	997	997	706	706	705
R-squared	0.030	0.046	0.352	0.570	0.555	0.553

Note: Robust standard errors in parentheses; * p<0.1, ** p<0.05, *** p<0.01.

OLS = ordinary least squares.

Source: Authors.

Table A8.7: Marginal Effects of the Ordered Probit Regression Results for Factors Affecting Perceived Quality (Health Risk) of Water from the Piped Water Network in both the Dry and Rainy Season

Dependent variable – Perceived health risk of water in different seasons (1=no risk, 2=little risk, 3=some risk, 4=serious risk)

Variables	Dry Reason (1)	Rainy Season (2)
Wealth group: poor	0 (.)	0 (.)
Wealth group: middle	−0.00330 (0.0931)	0.0709 (0.0956)
Wealth group: rich	−0.0236 (0.112)	−0.0855 (0.115)
Ethnicity1: Newar	0 (.)	0 (.)
Ethnicity2: Brahman	0.656*** (0.117)	0.692*** (0.121)
Ethnicity3: Other janjati	−0.516 (0.490)	−0.373 (0.500)
Ethnicity4: Dalit	0.756*** (0.207)	0.812*** (0.213)
Ethnicity5: Madhesi Others	0.671 (0.549)	0.443 (0.566)
Road1: dirt	0 (.)	0 (.)
Road2: pitch	0.308** (0.127)	0.295** (0.131)
Road3: stone/brick	−0.362*** (0.126)	−0.382*** (0.131)
Perceived color of water (ranges from 1 for very clean to 4 for very dirty)	0.294*** (0.0886)	0.667*** (0.0933)
Perceived taste of water (ranges from 1 for excellent to 4 for poor)	0.538*** (0.0737)	0.583*** (0.0751)
Education0: no education	0 (.)	0 (.)
Education1: primary and non-formal	−0.136 (0.267)	−0.176 (0.279)
Education2: secondary and above	−0.0927 (0.265)	−0.0520 (0.277)
Ward FE	Yes	Yes
Cut 1 constant	1.306*** (0.375)	1.997*** (0.389)

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Table A8.7 *continued*

Variables	Dry Reason (1)	Rainy Season (2)
Cut 2 constant	2.131*** (0.378)	2.657*** (0.392)
Cut 3 constant	3.329*** (0.384)	4.206*** (0.405)
N	820	827
Pseudo R-squared	0.199	0.251

Note: Standard errors in parentheses * p<0.1, ** p<0.05, ***p<0.01.

Source: Authors.

9

A Spatial Panel Modeling of Water and Sanitation Insecurity and Policy Implications in South Asia: Evidence from Bangladesh

M. Mizanur Rahman Sarker and Hidetoshi Yamashita

9.1 Introduction

Water and sanitation are essential for local development, particularly for sectors such as health, agriculture, social and economic development, education, and the environment. However, 748 million people in the world lack access to an improved source of drinking water and 2.5 billion people live without basic sanitation facilities. Around 1.7 billion people in Asia and the Pacific have no access to modern sanitation (ADB 2014), and water demand is projected to increase by about 55% due to growing demand from domestic and industrial sectors. Recent estimates indicate up to 3.4 billion people could be living in water-stressed areas of Asia by 2050 (ADB 2018).

Bangladesh has enjoyed almost universal access to secure drinking water for many years, but the arsenic pollution of 22% of the country's tube wells lowered the service coverage to below 80%. This incredible achievement in a deprived, mainly rural, and significantly overpopulated country was made possible primarily through the market-based expansion of low-cost hand pumps, allowing to access groundwater instead of the polluted surface waters. Drinking water access is widespread, but half of the drinking water consumed fails to meet water safety standards. In urban areas of Bangladesh, piped water supply reaches only about a third of the population, and there is no systematic sewer disposal and treatment system. Only Dhaka, the capital, has a sewer system, which serves just 18% of the city.

Modeling the spatial variation of the use of insecure water sources and sanitation in Bangladesh is very important for a number of reasons. Unsafe drinking water and poor sanitation can be significant carriers of diseases such as cholera, typhoid, and schistosomiasis. In many developing countries, the aggregate and regional use of improved sanitation and drinking water sources is one of the most important indicators of economic and social well-being (Araral and Yu 2013). Drinking water can also be tainted with chemical and physical contaminants with harmful effects on human health. In addition to its association with disease, access to drinking water may be particularly important for women and children, especially in rural areas, who bear the primary responsibility for carrying water, often for long distances. Inadequate disposal of human excreta and personal hygiene are associated with a range of diseases, including diarrheal diseases and polio, and are important determinants for stunting. Improved sanitation and safe water can reduce diarrheal disease by more than one-third, and can significantly lessen the adverse health impacts of other disorders responsible for death and disease among millions of children in developing countries.

Water and sanitation are at the core of sustainable development critical to the survival of people and the planet. Among the Sustainable Development Goals (SDGs) adopted by the United Nations in September 2015, SDG6 (clean water and sanitation) includes target 6.1 to achieve universal access to safe drinking water and target 6.2 to achieve universal access to sanitation and hygiene by 2030 to those in vulnerable situations. Bangladesh has made significant progress in reducing open defecation, from 34% in 1990 to all most 100% of the national population in 2015. However, the current rate of improved sanitation is 61%, growing at only 1.1% annually (World Bank 2016a). Still, the quality of sanitation coverage is an emerging area of concern, with more than 40% of all latrines classified as unimproved and/or insecure. Unimproved latrines include so-called hanging latrines and other types, which pose the same health risks as open defecation. Bangladesh's achievements in increasing household latrine use are the result of a combination of different forces, and the 17 SDGs and their targets are closely interlinked.

Many researchers have investigated the cause, characteristics, consequences, and issues related to the use of sanitation and drinking water sources such as public health. However, only one study on arsenic pollution has considered the spatial dependency in Bangladesh (Sarker 2012), and it concluded that spatial effects matter and improve the explanatory power of the model. Spatial econometrics are becoming more popular in the social sciences. Economists and other social scientists increasingly using econometric models to examine spatial interactions among economic units, with important advances reported both in theoretical and empirical studies (Anselin 2001, 2002; Anselin and Bera 1998). Econometric techniques have been developed to capture spatial processes effectively in natural or experimental data (Anselin 1988, 2001; Coughlin, Garrett, and Murillo 2004; Haining 1990). Spatial dependence means a relationship in which observations both lack independence and have a spatial structure underlying these correlations (Anselin and Florax 1995). While the application of explicit spatial econometric methods has increased tremendously in the social sciences in general and economics in particular (Anselin 2001), only a few studies to date have employed spatial regression analysis in the study of health-related data in South Asia (Sarker 2012). When spatial dependence is ignored, the statistical interpretation of the regression model will be wrong. While looking at the problem from a regional perspective, this body of work ignores the importance of controlling for spatial interactions and spillover effects due to adjacency, and the implications for the strength and validity of relationship. In this regard, different economic and demographic factors are associated with the national and regional use of improved or insecure sanitation and water sources. To the best of our knowledge, however, few studies have attempted to explain regional disparities of the use of sanitation and drinking water sources in Bangladesh despite the emergence of works on the issue in recent years. We implement a spatial panel data model for empirical evidence to estimate the effects that control for the spatial autocorrelation due to neighboring regions and the district-level heterogeneity across regions.

This chapter investigates the disparities in the district and regional use of insecure drinking water sources and sanitation, as well as the determinants of insecure drinking water sources and sanitation in Bangladesh. In this context, this chapter addresses the gap in past literature by exploring the question whether and to what extent spatial mechanisms are involved in the use of insecure drinking water and sanitation by employing a spatial panel data approach, explicitly considering the role of spatial effects within a panel data approach. Therefore, the aim of this chapter is to identify the determinants of use of insecure water and sanitation sources and estimate their spatial dependency.

9.2 Methodology

This section describes our empirical strategy based on the spatial panel data approach. Panel data contain observations of multiple phenomena obtained over multiple time periods for the same units. There are two different sets of information that can be derived from cross-sectional and time series data. The cross-sectional part of the data set reflects the differences observed between the individual subjects or entities, whereas the time series section reflects the differences observed for one subject over time. In general, panel data models are more efficient than pooling cross-sections, since the observation of one individual for several periods reduces the variance compared to repeated random selections of individuals. Several variables are selected in the analysis as proxy variables for awareness, aspiration, ignorance, insensitivity, and incapability. In this context, a balanced panel model is fitted for the time period ranges from 2010 to 2014. The data of the 64 districts of Bangladesh for 2 years (2010 and 2014) were used for the analysis of this study. The data for the panel analysis were collected from eight sources.

9.2.1 Data Sources

The data used in this chapter were collected from various sources. The two major sources are: (i) Bangladesh Multiple Indicator Cluster Survey (MICS) 2012–13 (BBS-UNICEF 2014) and (ii) Bangladesh MICS 2009 (BBS-UNICEF 2010) for percentage of use of insecure drinking water and sanitation, proportion of children engaged in work, and access to mass media and information and communication technology (ICT) of women. The sample for the Bangladesh MICS was designed to provide estimates on indicators on the situation of children and women in urban and rural areas at the national, district, and *upazila* levels. *Upazilas* were selected as the main sampling domains throughout the country, and the sample was selected in two stages. For MICS 2012–13, 51,895 of 55,120 households selected for the sample were interviewed, with 52,711 households found to be occupied. The household response rate is 98.5%. Within each *upazila* throughout the country, 26 census enumeration areas (EA) were selected with probability proportional to their size in MICS 2009. Within each EA, a segment of 20 households was drawn randomly for survey. Of the 300,000 households selected for the sample, 299,988 were found to be occupied. Of these, 299,842 were interviewed successfully for a household response rate of 99.9%.

Other sources were the following: (iii) Statistical Pocket Book of Bangladesh (BBS 2010a) and (iv) Statistical Pocket Book of Bangladesh

(BBS 2014a) for average household size of different districts, (v) Statistical Yearbook of Bangladesh (BBS 2010b) and (vi) Statistical Yearbook of Bangladesh (BBS 2014b) for literacy rates, and (vii) Directorate of Agricultural Extension personnel and (viii) Bangladesh Rice Research Institute (Agricultural Economics Division) for the daily average wage rate of agricultural labor for both 2010 and 2014.

9.2.2 Estimation Technique

Our purpose in this section is to estimate the causal effect of the use of insecure drinking water and sanitation and estimate the spatial dependency. There are some challenges in estimating the models for the determinants of the use of insecure water sources and sanitation, particularly regarding how the unobserved heterogeneity and potential endogeneity of some of the variables are addressed. We use a spatial panel model to assess these effects. Moreover, we investigate the significance of spatial interactions of the disparate use of insecure water sources and sanitation facilities. Several variables proposed in the literature are considered as proxy variables for awareness, aspiration, ignorance, insensitivity, and incapability, which affect the level of the regional use of insecure sanitation and drinking water. In this study, the variables are selected according to the availability of data at the level of 64 districts for the years 2010 and 2014. Below we discuss the estimated models and how these issues are addressed in this analysis.

The interaction between locations can be analyzed considering the following two issues: (i) spatial dependency and (ii) spatial heterogeneity. Spatial dependency is the interaction of a location in space to its adjacent location or locations. It is a property of a spatial stochastic process in which the outcomes at different locations may be dependent. Often, we can measure dependence in terms of the covariance or correlation of the random variables.

$$\text{Spatial dependency: } y_i = f(y_j),\ i=1, \ldots\ n \text{ and } i \neq j;$$

The spatial dependency, binary weight matrix, and standardized weight matrix are shown in Figure 9.1.

Spatial variation is the non-constant variance of the spatial data from one location to another. This interaction is described as a spatial lag model that indicates the relationship between dependent variables and spatial error model that indicates the relationship between error terms. A spatial lag model is a formal representation of the outcome of processes of social and spatial interaction. A spatial lag, or regressive

Figure 9.1: Spatial Dependency, Binary Weight Matrix, and Standardized Weight Matrix

Common border;
District $y_1 = \{y_2, y_{11}\}$ in row 1.
District $y_2 = \{y_1, y_3, y_4, y_7, y_{11}\}$ in row 2.

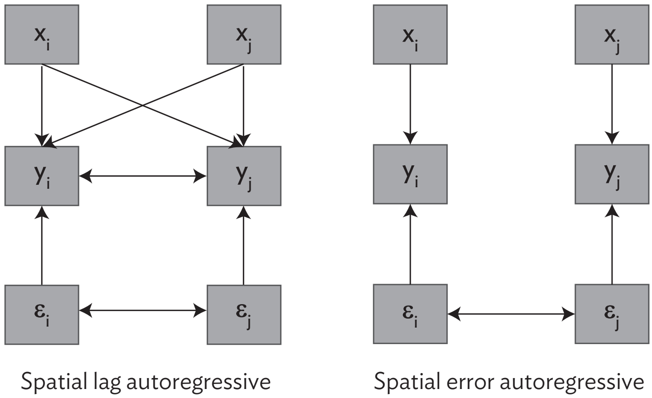
$$W = \begin{bmatrix} 0&1&0&0&0&0&0&0&0&0&1 \\ 1&0&1&1&0&0&1&0&0&0&1 \\ 0&1&0&1&0&0&0&0&0&0&0 \\ 0&1&1&0&1&1&1&0&0&0&1 \\ 0&0&0&1&0&1&0&0&0&0&0 \\ 0&0&0&1&1&0&1&0&0&0&0 \\ 0&1&0&1&0&1&0&1&0&0&1 \\ 0&0&0&0&0&0&1&0&1&0&1 \\ 0&0&0&0&0&0&0&1&0&1&1 \\ 0&0&0&0&0&0&0&0&1&0&1 \\ 1&1&0&1&0&0&1&1&1&1&0 \end{bmatrix} \quad W_S = \begin{bmatrix} 0&1/2&0&0&0&0&0&0&0&0&1/2 \\ 1/5&0&1/5&1/5&0&0&1/5&0&0&0&1/5 \\ 0&1/2&0&1/2&0&0&0&0&0&0&0 \\ 0&1/6&1/6&0&1/6&1/6&1/6&0&0&0&1/6 \\ 0&0&0&1/2&0&1/2&0&0&0&0&0 \\ 0&0&0&1/3&1/3&0&1/3&0&0&0&0 \\ 0&1/5&0&1/5&0&1/5&0&1/5&0&0&1/5 \\ 0&0&0&0&0&0&1/3&0&1/3&0&1/3 \\ 0&0&0&0&0&0&0&1/3&0&1/3&1/3 \\ 0&0&0&0&0&0&0&0&1/2&0&1/2 \\ 1/7&1/7&0&1/7&0&0&1/7&1/7&1/7&1/7&0 \end{bmatrix}$$

Spatial dependency | Binary weight matrix | Row-standardized W matrix

spatial autoregressive model, includes a spatially lagged dependent variable on the right hand side of the regression specification (Anselin 1988). A second approach to spatial autoregressive process or spatial autoregressive modeling is known as the spatial error model. The spatial lag model tracks how the response variable relates to its value in surrounding locations (the spatial lag), while controlling for the influence of other explanatory variables. If some ignored element of error terms shows a significant spatial pattern, it will be reflected in a spatial pattern. A dependent variable y in place i is affected by the independent variables in both place i and j. With spatial lag in ordinary least squares (OLS) regression, the assumption of uncorrelated error terms is violated and the assumption of independent observations is also violated. As a result, the estimates are biased and inefficient. The relations among the variables in the presence of spatial dependency are shown in Figure 9.1. The error terms across different spatial units are correlated. With spatial error in OLS regression, the assumption of uncorrelated error terms is violated. As a result, the estimates are inefficient. The relationship among the variables and spatial lag and error term are shown in Figure 9.2.

In this study, we used a spatial panel econometric method based on spatial autocorrelation techniques to explore the district and divisional distribution of use of insecure drinking water sources and sanitation. Consider a general spatial panel model for individual i in time t, which relates outcomes y to observable individual attributes, which allows for spatial dependence in the dependent variable or in the error component:

Figure 9.2: Relationship among the Spatial Lag and Error Autoregressive Variables



Spatial lag panel model

$$y_{it} = X_{it}\beta + \rho W y_{it} + \mu_i + \varepsilon_{it} \tag{1}$$

Spatial error panel model

$$\begin{aligned} y_{it} &= X_{it}\beta + \mu_i + v_{it} \\ v_{it} &= \lambda W v_{it} + \varepsilon_{it} \end{aligned} \tag{2}$$

where y_{it} is the outcome of interest. For the independent variables, X_{it} is a matrix of the vector of the explanatory and control variables measured at time t. The scalars ρ and λ are spatial lag and spatial error coefficients, respectively. Wy_{it} and Wv_{it} are exogenously specified n × n spatial weight matrices, lag, and error, respectively. μ_i is an unobservable individual specific effect and ε_{it} is the idiosyncratic error term. The spatial weight matrix is the fundamental tool used for representing the spatial connectivity between regions. The adjacent relationship between locations is indicated by a spatial weight matrix. In this study, two separate models are estimated by constructing two different spatial weight matrices for each of them.

First, the spatial weight matrix is based on constructing contiguity (common boundary). It is constructed using the neighborhood border: if two locations are neighbors (share a border), its value is 1; if not, its value is 0. For the estimation of spatial regression models, the spatial weight matrix should be row-standardized to yield a meaningful interpretation of the results. The row standardization consists of dividing each element in a row by the corresponding row sum (Figure 9.1); hence, it effectively includes a weighted average of neighboring values into the regression equation.

Second, the spatial matrix is constructed according to inverse distance, the so-called inverse distance matrix. A limitation of the binary weight matrix is that it assumes equal weights across all bordering spatial neighbors and does not allow the effective capture of spatial distances across all cross-sectional units. Measures of spatial contiguity include (i) the distance specification between districts, where $w_{ij} = 1/d_{ij}$; (ii) the inverse distance squared, where $w_{ij} = 1/d^2_{ij}$; and (iii) exponential distance decay, where $w_{ij} = exp(-d_{ij})$. As the distance between districts i and j increases (decreases), w_{ij} decreases (increases), thus giving less (more) spatial weight to the district pair when $i \neq j$. In all cases, $w_{ij} = 0$ for $i = j$. While there is no consensus on how distance between cross-sectional units should be measured, we consider the distance between district population centers, following Hernández-Murillo (2003); Coughlin, Garrett, and Murillo (2004); and Sarker (2012).

The preferred approach for testing the spatial effects in spatial panel models is based on the Lagrange multiplier (LM). While neglecting the spatial dependence structure causes biased and inconsistent estimates, ignoring the spatial error leads to precision problems but not biased estimation. Spatial error indicates the variables that are not included in the model. In other words, it is the identification error of the model. LM tests decide how spatial dependency is included in the model. They provide a good guide for which specification between spatial error and spatial lag is the most appropriate. Bera and Yoon (1993) proposed a modification of the LM test that is robust like that of Anselin (1988). After the widespread use of the spatial effects in panel data analysis, Anselin, Le Gallo, and Jayet (2006) developed these tests for panel data analysis.

Thus, the spatial panel model to be estimated can be expressed as follows:

Spatial lag panel model

$$
\begin{aligned}
y_{it} &= \rho W y_{it} + \beta_0 + \beta_1 hhsize_{it} + \beta_2 lrate_{it} + \beta_3 clabour_{it} \\
&\quad + \beta_4 dwroal_{it} + \beta_5 atmmictw_{it} + \beta_6 fhh_{it} + \mu_i + \varepsilon_{it}
\end{aligned} \tag{3}
$$

Spatial error panel model

$$\begin{gathered} y_{it} = \beta_0 + \beta_1 hhsize_{it} + \beta_2 lrate_{it} + \beta_3 clabour_{it} \\ + \beta_4 dwroal_{it} + \beta_5 atmmictw_{it} + \beta_6 fhh_{it} + \mu_i + v_{it} \\ v_{it} = \lambda W v_{it} + \varepsilon_{it} \end{gathered} \tag{4}$$

where y_{it} is percentage of use of insecure water sources and sanitation, *hhsize* is household size, *lrate* is literacy rate, *clabor* is child labor, *dwroal* is daily wage rate of agricultural labor, *atmmictw* is access to mass media and ICT of women, and *fhh* is percentage of female-headed households for a district of Bangladesh.

Fixed and random effects models are discussed during the study of panel data analysis. Unobservable effects that cause model specification errors when not included in the model are taken as fixed and are defined as fixed effects models. On the other hand, random effects models are used when unobservable effects are included in the error term of the model. The unobservable effects are related to the independent variables in the fixed effects model, whereas it is not the case for the random effects model. If there is a relationship between independent variables and the error term, the estimates that are obtained from the fixed effects models will be biased and inconsistent. Because there is no such relationship in the random effects model, the estimation results provide the best unbiased estimators. These estimators are consistent and asymptotically efficient. The best estimators are identified by using the Hausman (1978) and Baltagi (2008) tests.

Panel data analysis helps us determine the observed changes both across the regions and through the years. First, according to the contiguity-based spatial weight matrix, the spatial dependency is tested using the LM test. Both the LM test for spatially lagged endogenous variable (LM-Lag) and the LM test for residual spatial autocorrelation (LM-Error) rejected the null hypothesis of no spatial dependence. Second, according to the inverse distance weight matrix, both LM-Lag and LM-Error test results are rejected. According to the inverse distance, spatial dependencies are included as a spatial error in the model. Both the test results are found positive and significant, indicating the presence of spatial autocorrelation, as shown in Tables 9.2 and 9.4. However, because the LM-Lag test results rejected the null hypothesis more precisely than the LM-Error test results, with a value of 10.846 and significant at 1% by a t-test ratio, spatial dependence is included in the model as a spatial error (Table 9.1). This implies that if we ignore spatial dependency, the results will be biased.

According to the contiguity-based spatial weight matrix model, after the results of the Hausman test, the estimation of the random effects model is decided when unobservable variables are included in the model error term and are not related to independent variables. This indicates that changes occur in the regressor through time but not if the model is random. According to the LM and Hausman tests results, the estimation of the random effect spatial lag model uses the contiguity-based spatial weight matrix for insecure water and the fixed effect spatial lag model for insecure sanitation. According to the inverse distant spatial weight matrix model, the LM and Hausman test results of the estimation of the fixed effect spatial lag model are decided for both the use of insecure water sources and sanitation.

9.2.3 Regional and Divisional Spatial Panel Model

The basic spatial panel model detailed above assumes that the influence of spatial dependence is the same for all districts. To reveal differences in spatial correlation for geographic regions, we modify equations (3) and (4) to allow for different spatial correlation coefficients in four divisions and two regions of Bangladesh. We use four ex-administrative divisions in the contiguous 64 districts. The spatial panel model with divisional and regional spatial correlation coefficients may be written as:

Spatial lag panel model

$$y_{it} = \sum_{k=1}^{D} \rho_k W_k y_{it} + X_{it}\beta + \mu_i + \varepsilon_{it} \tag{5}$$

Spatial error panel model

$$y_{it} = X_{it}\beta + \mu_i + v_{it} \tag{6}$$

where $v_{it} = \sum_{k=1}^{6} \lambda_k W_k v_{it} + \varepsilon_{it}$

Here, k denotes the divisions/regions, and ρ_k and λ_k denote the spatial lag and spatial error lag coefficients, respectively, for division k. Each coefficient, ρ_k, measures the average correlation between a district in a division/region k and the spatially weighted use of insecure water sources and sanitation of all other districts. W_k remains the (N×N) spatial weights matrices w_k. Each matrix W_k is constructed by pre-multiplying by a dummy variable that equals unity if district i is located in division/region k, and 0 otherwise. In the case of a contiguity matrix, the use of insecure water sources and sanitation of district i located in division k

may be affected by the use of insecure water sources and sanitation of all districts *j* that border district *i*, regardless of whether district *j* is in the same division/region as district *i*.

9.3 Results and Discussions

9.3.1 Spatial Estimates with Contiguity Weights Matrices for the Use of Insecure Water

The estimation results of panel OLS and panel random effects models without spatial effects are shown in Table 9.1. Based on the LM and Hausman tests, there is a significant spatial dependence in the set of residuals that is found in the model, thus the estimation results of the spatial random effects model with the contiguity weight matrices are

Table 9.1: Regression Results with Contiguity Weight Matrices for the Use of Insecure Water

	OLS		Panel Random Effects		Spatial Lag Panel Random	
	Coefficient	Standard Error	Coefficient	Standard Error	Coefficient	Standard Error
Household size	8.190**	4.039	7.842**	3.752	7.524**	3.766
Literacy rate	−0.295***	0.103	−0.336***	0.093	−0.178***	0.051
Child labor	0.121**	0.054	0.207**	0.098	0.201***	0.078
Daily wage rate of agricultural labor	−0.352**	0.169	−0.432***	0.105	−0.413**	0.189
Access to mass media and ICT of women	−0.404**	0.201	−0.316**	0.143	−0.248**	0.113
Female-headed household	−0.625	0.516	−0.812	0.608	−0.788*	0.438
Constant	45.142***	15.098	38.073***	10.022	31.575**	14.553
Spatial lag coefficient (Rho)					0.339**	0.109
R-square	0.549		0.521		0.661	
LM-Lag			10.846***	2.368		
LM-Error			9.674***	2.103		

ICT = information and communication technology, LM = Lagrange multiplier, OLS = ordinary least squares.
Note: ***p<1%, **p<5% and *p<10%.
Source: Authors.

provided in the third model of Table 9.1. In addition, the significance of the spatial coefficient observed over the period is another important result taken from estimates. The results of the analyses show that it is important to consider that districts are not isolated entities and that there is a significant spatial interaction among districts. Therefore, disparities among the districts in Bangladesh in the use of insecure water are tested using LM tests. Spatial autocorrelation is found according to the test results of LM-Lag and LM-Error. Because of the more precise results of LM-Lag, spatial dependence is included in the model as spatial lag. As a result, a positive spatial correlation is observed among the district-level distribution of the use of insecure water in Bangladesh.

Of the six variables, household size, literacy rate, child labor, daily wage rate of agricultural labor, and access to mass media and ICT of women seem to explain most of the district-level use of insecure sanitation for the 64 districts, whereas the percentage of female-headed households variable does not seem to affect the district-level use of insecure water between 2010 and 2014. The positive sign for the coefficients indicate that the increase of the value of the variable increases the use of insecure water. On the other hand, the negative sign for the coefficients indicate that the increase of the value of the control variable decreases the use of insecure water. Bandarban district has lower education (36.15%) and therefore higher water insecurity (54.2%). Mymensingh district has lower water insecurity (0%) because its neighbor Kishoreganj has low water insecurity (0%).

9.3.2 Spatial Estimates with Inverse Distance Weight Matrices for the Use of Insecure Water

Table 9.2 presents the spatial estimation results with inverse distance weight matrices three alternative specifications for the use of insecure sanitation. Model 1 in Table 9.2 corresponds to a standard regression model where no spatial effects among the neighboring districts are taken into account. The spatial autocorrelation is found according to the test results of LM-Lag and LM-Error. However, the test results of LM-Error are more powerful than those of LM- Lag.

Model 2 corresponds to a specification where the panel random effect among the districts is accounted for on the basis of the Hausman test. Finally, model 3 corresponds to a specification where the spatial panel random effect among the districts is accounted for on the basis of LM and Hausman tests. Results from Table 9.2 indicate that coefficients of spatial dependence are statistically significant. The spatial coefficient indicates the presence of an interaction among the districts. This model suggests that the use of insecure water of households of a district

Table 9.2: Regression Results with Inverse Distance Weight Matrices for the Use of Insecure Water

	OLS		Panel Random Effects		Spatial Panel Random Effects	
	Coefficient	Standard Error	Coefficient	Standard Error	Coefficient	Standard Error
Household size	8.250**	4.039	7.842**	3.752	8.422**	4.071
Literacy rate	−0.295***	0.103	−0.336***	0.093	−0.288***	0.079
Child labor	0.121**	0.010	0.114***	0.042	0.138***	0.038
Daily wage rate of agricultural labor	−0.352**	0.169	−0.432***	0.105	−0.377**	0.175
Access to mass media and ICT of women	−0.404**	0.201	−0.316**	0.143	−0.394**	0.179
Female-headed household	−0.625	0.516	−0.812	0.608	−0.643	0.472
Constant	45.142***	15.098	38.073***	10.022		
Spatial error coefficient					0.246**	0.113
R- square	0.549		0.521		0.572	
LM-Lag			7.852***	2.243		
LM-Error			8.374***	2.294		

ICT = information and communication technology, LM = Lagrange multiplier, OLS = ordinary least squares.
Note: ***p<1%, **p<5% and *p<10%.
Source: Authors.

depends positively on neighboring district households' use of insecure water. This implies an identification error in the model because spatial dependence is neglected in the model; thus, it is included in the error term of the model. The coefficients represent the effects of the explanatory variables on the use of insecure water. The average household size of Sylhet district is higher (4.76 persons/household), and it therefore has higher water insecurity (26.2%). Khagrachhari district has higher water insecurity (30.2%) because its neighbor Rangamati has high water insecurity (29.3%).

9.3.3 Spatial Estimates with Contiguity Weights Matrices for the Use of Insecure Sanitation

The estimation results of OLS and panel fixed effects models without spatial effects are shown in columns 1 and 3 of Table 9.3 for the use of insecure sanitation. Based on the LM tests, there is a significant spatial dependence in the set of residuals that is found in the model; thus, the estimation results of the spatial fixed effects model with the contiguity weight matrices are provided in the third column of Table 9.3.

Table 9.3: Regression Results with Contiguity Weight Matrices for the Use of Insecure Sanitation

	OLS		Panel Fixed Effect		Spatial Panel Fixed Effect	
	Coefficient	Standard Error	Coefficient	Standard Error	Coefficient	Standard Error
Household size	4.082**	1.993	3.820**	1.71	3.708***	1.241
Literacy rate	−0.034**	0.016	−0.075**	0.033	−0.094**	0.043
Child labor	0.152***	0.027	0.162**	0.031	0.115**	0.0214
Daily wage rate of agricultural labor	−0.369***	0.125	−0.373***	0.142	−0.401***	0.123
Access to mass media and ICT of women	−0.206**	0.098	−0.185***	0.042	−0.159***	0.038
Female-headed household	−0.503	0.346	−0.486	0.328	−0.587*	0.339
Constant	91.891***	18.598				
Spatial lag coefficient					0.474***	0.084
R- square	0.543		0.582		0.617	
LM-Error			12.104***	2.480		
LM-Lag			12.866***	2.512		

ICT = information and communication technology, LM = Lagrange multiplier, OLS = ordinary least squares.
Note: ***p<1%, **p<5% and *p<10%.
Source: Authors.

The results of the analyses show that it is important to consider that districts are not isolated entities for the use of insecure sanitation and that there is a significant spatial interaction among districts. Therefore, a spatial relationship among districts' use of insecure sanitation disparities in Bangladesh is tested by using LM tests. Then, the spatial autocorrelation is found according to the test results of LM-Lag and LM-Error like use of insecure sanitation. Because of more precise results of LM-Lag, spatial dependence is included in the model as spatial lag. As a result, a positive spatial correlation is observed among the district-level distribution of the use of insecure sanitation in Bangladesh. Bandarban district has lower education (36.15%) and therefore higher sanitation insecurity (82.3%). Sherpur district has higher sanitation insecurity

(62.3%) because its neighbor Jamalpur has high sanitation insecurity (60.9%).

9.3.4 Spatial Estimates with Inverse Distance Weight Matrices for the Use of Insecure Sanitation

Table 9.4 presents three alternative specifications of the spatial estimation results with inverse distance weight matrices for the use of improved sanitation. Model 1 in Table 9.4 corresponds to a standard regression model where no spatial effects among the neighboring districts are taken into account. The coefficients represent the effects of the explanatory variables on the use of insecure sanitation. Model 2 corresponds to a specification where the panel fixed effect among the districts is accounted for on the basis of the Hausman test. Finally, model 3 corresponds to a specification where the spatial panel fixed effect among the districts is accounted for on the basis of LM and Hausman tests. The null hypothesis of the Hausman test is that the random effects model is appropriate for the particular sample compared to the fixed effects model. Both random effect (RE) and fixed effect (FE) estimations rely on the OLS assumptions. When these assumptions are met, the theory states that FE estimation is unbiased and consistent but the time-invariant variables cannot be included in the in the panel data analysis. RE estimation requires an additional assumption: the group-level effect and the included explanatory variables must be independent. When this assumption is met, RE estimation is unbiased, consistent, and efficient, although time-invariant variables can be included in the analysis. Thus, when the objective of an analysis is to measure the effect of group-level variables, FE estimation is not a workable method and not efficient. If the hypothesis of the Hausman test is accepted, then RE estimation is superior to FE estimation, because although both estimators are unbiased and consistent only RE is efficient.

Blindly applying any estimator can lead to bias, inefficiency, and flawed inference. If the policy maker makes decisions using this misguided inference, the policy may be wrong and mislead the policy maker and the nation. Therefore, in our case, the Hausman test assists the policy maker to decide on appropriate policy by using the correctly specified estimated model.

The results shown in Table 9.4 indicate that coefficients of spatial dependence are statistically significant. The spatial lag coefficient indicates the presence of interaction among the districts. This model suggests that the use of insecure sanitation of households of a district depends positively on neighboring district households' use of insecure sanitation. The findings of model 3 of Table 9.4 suggest that a 1% increase in the literacy rate, on average, leads to a decrease of about 0.09% of the use of insecure sanitation. A decrease in household sized (that is, the number of persons who live together and take food from the same kitchen) of one person per household is associated with an increase in the use of insecure sanitation by an average of 3.64%. Average household size seems to be a proxy for the presence or lack of social awareness. Large household size generally indicates social backwardness, including social or and religious superstitions (false belief). Bhola district has a larger household size (4.76 persons) and therefore higher sanitation insecurity (59.7%). Comilla district has lower sanitation insecurity (23.3%) because its neighbor Chandpur has lower sanitation insecurity (26.0%).

Table 9.4: Regression Results with Inverse Distance Matrices for the Insecure Sanitation

	OLS		Panel Fixed Effects		Spatial Panel Fixed Effects	
	Coefficients	Standard Error	Coefficients	Standard Error	Coefficients	Standard Error
Household size	4.082**	1.993	3.820**	1.71	3.644**	1.702
Literacy rate	−0.034**	0.016	−0.075**	0.033	−0.087***	0.024
Child labor	0.146***	0.062	0.166**	0.079	0.172**	0.084
Daily wage rate of agricultural labor	−0.369***	0.125	−0.373***	0.142	−0.384***	0.096
Access to mass media and ICT of women	−0.206**	0.198	−0.185**	0.094	−0.174**	0.086
Female-headed household	−0.503	0.346	−0.486	0.328	−0.396	0.382
Constant	91.891***	18.598				
Spatial lag coefficient (Rho)					0.263***	0.066
R- square	0.543		0.582		0.602	
LM-Error			9.508***	2.971		
LM-Lag			9.672***	2.878		

ICT = information and communication technology, LM = Lagrange multiplier, OLS = ordinary least squares.

Note: ***p<1%, **p<5% and *p<10%.

Source: Authors.

9.3.5 Regional Disparities of the Use of Insecure Water Sources

The findings presented in Tables 9.1 and 9.2 indicate that spatial dependence of spatial panel random effect model with binary contiguity weights matrices using a spatial lag for the use of insecure water sources may be the best model among the specifications. Therefore, we only consider divisional and regional differences in spatial lag coefficients among the specifications. Model 1 reports the estimates from the spatial panel random effect model that allows for region-specific spatial lag coefficients at the administrative division level, while model 2 allows for region-specific spatial lag coefficients at the regional (north, south) level when neighbors are defined as having a common border. Table 9.5 presents the results from two specifications that allow for regional and divisional differences in the spatial correlation coefficients by using binary weight contiguity.

Table 9.5: Regression Results of Spatial Panel Random Effect Estimate by Using Contiguity Weights for the Use of Insecure Water Source

	Divisional Spatial Lag		Regional Spatial Lag	
	Coefficient	Standard Error	Coefficient	Standard Error
Household size	10.263**	4.705	7.412**	3.103
Literacy rate	−0.153**	0.072	−0.169**	0.081
Child labor	0.146**	0.072	0.168**	0.084
Daily wage rate of agricultural labor	−0.385**	0.176	−0.416**	0.161
Access to mass media and ICT of women	−0.253**	0.116	−0.228**	0.104
Female-headed household	−1.061	0.747	−0.794	0.545
ρ1 (Dhaka)	0.333**	0.130		
ρ2 (Chittagong)	0.312**	0.148		
ρ3 (Khulna)	0.329**	0.126		
ρ4 (Rajshahi)	0.350**	0.170		
ρ1 (North)			0.331**	0.128
ρ2 (South)			0.337***	0.111
R- square	0.573		0.561	

ICT = information and communication technology.

Note: ***p<1%, **p<5% and *p<10%.

Source: Authors.

We find considerable evidence that the effects of spatial correlation in the dependent variable vary by division. As reported in model 2 of Table 9.5, two regional correlation coefficients are positive and statistically significant at the 1% level. Furthermore, visual inspection of the estimated coefficients suggests differences in the magnitude of the spatial correlation between a district in a given region and all other districts. Divisional spatial lag coefficients range from 0.312 to 0.350 and regional spatial lag coefficients vary between 0.331 and 0.337 using a spatial lag panel random effect model with binary broader contiguity weight matrices.

9.3.6 Regional Disparities of Spatial Panel Estimate of the Use of Insecure Sanitation

The findings from Tables 9.3 and 9.4 suggest that the spatial dependence in district-level use of insecure sanitation may be the best model using a spatial lag. In this case, the use of binary spatial weights is more appropriate to identify spatial interactions among the distance spatial weights of districts.

Table 9.6: Regression Results of Spatial Panel Fixed Effect Estimate by Using Contiguity Weights for the Use of Insecure Sanitation

	Divisional Spatial Lag Panel Fixed Effect		Regional Spatial Lag Panel Fixed Effect	
	Coefficient	Standard Error	Coefficient	Standard Error
Household size	10.889***	3.251	5.207**	2.385
Literacy rate	−0.055***	0.021	−0.038**	0.014
Child labor	0.174**	0.084	0.184**	0.093
Daily wage rate of agricultural labor	−0.278**	0.122	−0.370***	0.119
Access to mass media and ICT of women	−0.174**	0.087	−0.168**	0.083
Female-headed household	−1.243	0.937	−0.504	0.339
ρ1 (Dhaka)	0.308***	0.090		
ρ2 (Chittagong)	0.281**	0.129		
ρ3 (Khulna)	0.286**	0.127		
ρ4 (Rajshahi)	0.321***	0.118		
ρ1 (North)			0.288***	0.094
ρ2 (South)			0.203**	0.082
R- square	0.651		0.558	

ICT = information and communication technology.

Note: ***p<1%, **p<5% and *p<10%.

Source: Authors.

Therefore, we only consider the spatial lag panel fixed effect model with the common border contiguity weight matrices specification among the models for divisional and regional disparities of the use of insecure sanitation. The results are presented in Table 9.6 from two specifications that allow for regional and divisional differences in the spatial correlation coefficients. The spatial lag fixed effect regression results that allow for division-level spatial coefficients provide a similar picture as the region-level specifications. Estimates of positive and significant spatial correlations in four divisions range from 0.281 to 0.321 when neighbors are defined by a binary weight matrix. On the other hand, the estimates of spatial correlation in two regions are 0.288 and 0.203. Both regional spatial coefficients are positive and statistically significant ($p<0.01$). Six pair-wise hypothesis tests for four divisions and one test for two regions of the equality of the spatial correlation coefficients have been conducted. Test results show that the spatial correlation for districts in each division is not statistically homogeneous between Chittagong and Rajshahi and between two regions.

9.4 Conclusion

This chapter estimated the district and divisional disparities in the use of insecure water sources and sanitation in Bangladesh. A spatial panel data approach was applied to explore the determinants of the district and divisional level uses of insecure water sources and sanitation to derive empirical evidence as a step toward better understanding this relationship and its potential as a policy tool. The regional rates for the use of insecure sanitation vary between 82.7% and 18.28% and of insecure water sources between 54.2% and 1.0%. The results from spatial models clearly demonstrated that the use of insecure water sources and sanitation are a combination of the different control variables of individual districts as well as the use of insecure water sources and sanitation of their neighboring districts. This chapter found a clear and strong spatial structure at the district, divisional, and regional levels, with a higher spatial dependency mainly in Rajshahi division and the Northern region and a lower spatial dependency in Chittagong division and the Southern region. Spillover effects from neighboring districts' explanatory variables significantly influence the safe water and sanitation of a particular district.

Ensuring universal access to safe and affordable drinking water for all by 2030 requires us to invest in adequate infrastructure, provide sanitation facilities, and encourage hygiene at every level. There are some effective initiatives that have contributed to Bangladesh's remarkable progress in the water and sanitation sector, such as community-led total sanitation and water, sanitation access, and hygiene (WASH). The majority of water and sanitation facilities are financed from private sources. Sixty-five percent of the total funding available to the water and sanitation sector is financed by development partners and nongovernment organizations such as the Bill & Melinda Gates Foundation and the remainder by the government from tariffs and charges (World Bank 2016b). Community-led total sanitation might be the most exemplary Bangladeshi initiative. In countries across Asia, Africa, and Latin America, consensus has emerged that the best approach is community-led total sanitation, which is broadly recognized with changing people's behavior around the world to no longer defecate in the open, which has greatly improved global health. WASH has proven an effective initiative in the field for its behavior change campaigns and construction of many new toilets. Bangladesh is projecting lighthouse initiatives at schools which are WASH champion programs setting examples for many other countries with similar features. At present, 98% of the population gets drinking water from a technologically improved source and open defecation is around 0%.

The findings suggest that policy makers should realize that the use of secure water sources and sanitation in neighboring districts is likely to affect the use in their own district. Therefore, key issues for policy development at the national government level are how to decrease household size and child labor, stimulate educational attainment of men and women, promote the daily wage of agricultural labor, and improve access to mass media and ICT of women for increasing the use of healthy and hygienic sanitation and safe water sources. The national government decides the necessary policy to create awareness and ensure political and economic aspirations are achieved, especially in the regions of the country that lag in the use of secure sanitation and water sources as well as economically (Araral and Wang 2013). Finally, national-level policy makers could potentially use the findings to prioritize resource allocation, scale up efforts, and invest in the water and sanitation sector to achieve sustainable development.

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10

Water Policy and Institutions in the Republic of Korea

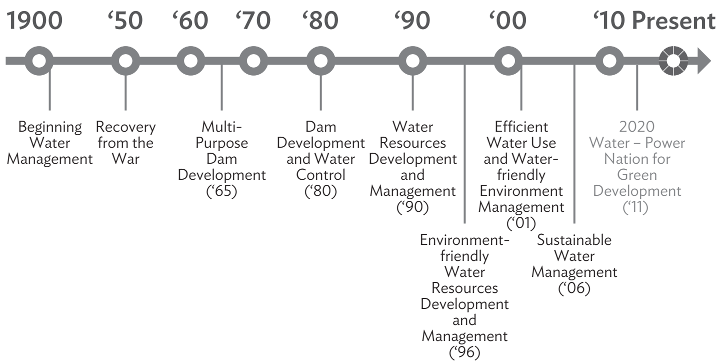
Namsoo Lee

10.1 Introduction

The Republic of Korea has been widely recognized for its rapid transformation from a war-devastated nation into one of the 10 largest economies in the world. The main driving forces are said to have been factors such as the comprehensive development plans laid out by the central government and strong leadership; industry development and export-centered policy; and foreign investment, high demand for education, and the diligence and solidarity of Koreans. Furthermore, investment in social overhead capital acted as a catalyst for social and economic development. Of these, policies to address the problems of chronic flooding and drought as well as the development of water resources to meet the country's ever-increasing demand acted as the backbone for its rapid economic development. Water policy and management started in the 1960s along with the national economic development plans. Figure 10.1 shows the chronological water management changes in the Republic of Korea. In the 1960s, a multipurpose dam development plan was set up by the central government, and several multipurpose dams and multi-water supply systems had been built by the 1990s. Since 2000, the water policy has increasingly focused on efficiency and environment-friendliness rather than development or expansion.

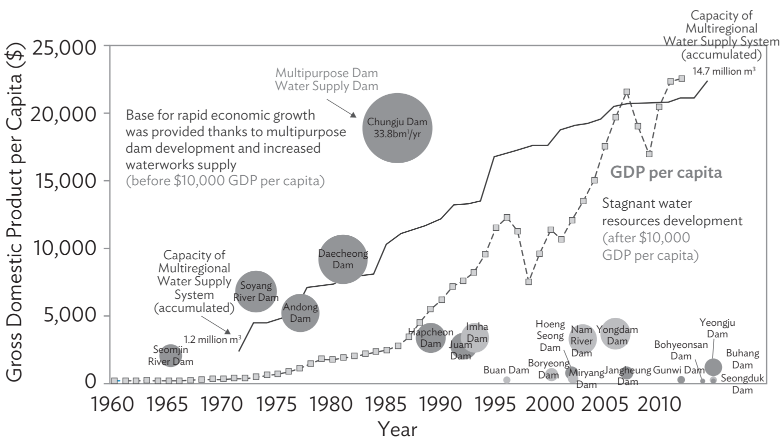
As shown in Figure 10.2, the central government built multipurpose dams and water resource infrastructure as laid out in the Comprehensive National Territorial Plan and the Long-Term Comprehensive Water Resources Plan. These acted as the basis for stimulating the country's economic development and were especially effective in the early stages. One unit of water resource development increased gross domestic product (GDP) by 0.577 units in the early stages of development, whereas

Figure 10.1: Water Management History in the Republic of Korea



Source: Ministry of Land, Infrastructure and Transport (2016).

Figure 10.2: Water Resources Development and Gross Domestic Product per Capita



Source: Ministry of Land, Infrastructure and Transport (2016).

in the mature stages of development, GDP has increased by 0.214 (Choi et al. 2016).

Developing countries tend to prioritize investment in roads, transportation, communication, and electricity ahead of water. However, water should also be regarded as a necessity both for the citizens' daily lives and industrial activities.

Systemized laws, institutions, and leadership are regarded as key factors for the successful development and maintenance of water resources in the Republic of Korea (Araral and Yu 2013).

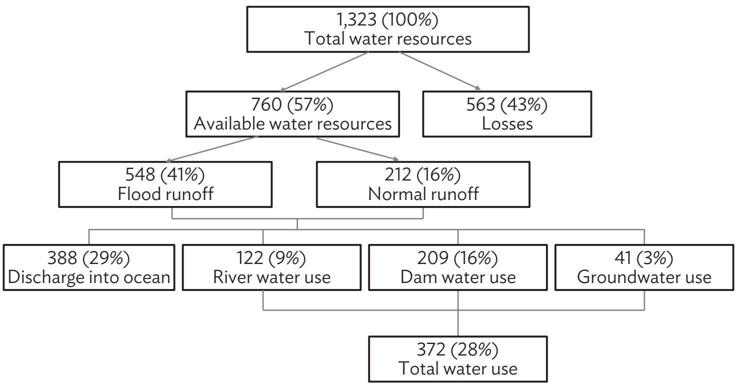
Recently, there has been a remarkable paradigm shift in water-related policy and institutions in the country (Araral and Yu 2013). For the integration of water resources management, which encompasses water quantity, water quality, aqua-ecosystem, and disaster prevention, among others, two main ministries related to the water management sector were combined. On 28 May 2018, the national congress determined that government organizations at the central level would be reorganized, with the Ministry of Environment managing the water sector in an inclusive way in terms of both water quantity and water quality.

10.2 Status of Water Resources

Water resources in the Republic of Korea total 132.3 billion cubic meters (m^3), of which 76.0 billion m^3 (57%) is available as shown in Figure 10.3. In 2014, total water use was 37.2 billion m^3, accounting for 28% of total water resources. Since the volume of total water use exceeds the amount of normal water runoff, which is measured during the normal non-flood season, flood runoff needs to be reserved in impoundments. Among the total amount of water use, household, industry, and agriculture use amounts to 25.1 billion m^3 per year, approximately 33% of the available water resources. The water use for households, industry, and agriculture are 7.6 billion m^3, 2.3 billion m^3, and 15.2 billion m^3, respectively.

Both seasonal and regional variations are shown in respect to water availability in the Republic of Korea. Yearly average precipitation is 1,274 millimeters (1.6 times the world average), more than half of which falls during a distinct rainy period (June to August), while winter precipitation is less than 10%. The rainy season brings frequent flash floods. In addition, the country's steep mountainous topography initiates high runoffs and reduces opportunity for soil infiltration, therefore also contributing to flooding. Regional disparities in rainfall are quite stark: the northeast parts (Gangwon) of the country experience over 1,400 millimeters of rainfall annually, whereas the southeast region (Gyeongsang including the so-called Central Nakdong River area) receives less than 1,100 millimeters of rainfall.

Figure 10.3: Water Resources Status in the Republic of Korea
(100 million cubic meters per year)



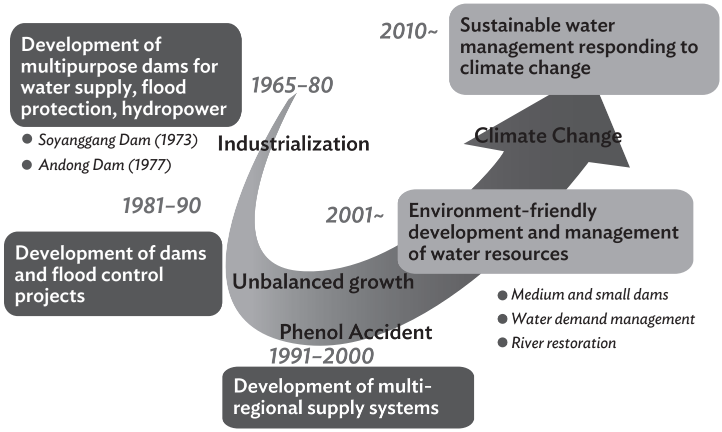
Source: Ministry of Land, Infrastructure and Transport (2016).

The Republic of Korea has had to adapt its water system to manage this variability and to provide even access to water supply across the country. This effort has materialized in the form of a sophisticated and extensive network of large, medium-sized, and small dams, irrigation facilities, and multiregional water systems aimed to provide water supply for domestic, industrial, and agricultural use; control river flows to prevent floods and droughts; and generate hydroelectricity. It was progressively developed from the 1980s to the early 2000s.

10.3 History of Water Resources Management Policy

The Republic of Korea's water policy commenced in the form of comprehensive water resources development projects starting with basin investigations in the 1960s after the Korean War. The comprehensive development projects included large-scale dams and water control projects in major rivers in the 1970s and 1980s. The concept of eco-friendly water resources management was born in the 1990s, and the focus on water supply and/or control moved to sustainable water management including stream environment preservation in the 2000s. Since 2010, the policy has focused on coping with climate change and advancing the water management system. The policy paradigm shift is shown in Figure 10.4.

Figure 10.4: Water Management Paradigm Shift



Source: K-water internal document.

10.3.1 The 1960s: Beginning of Comprehensive Water Resources Development

Establishment of Nationwide Water Resources Development and Management System

As the government accelerated land development from the 1960s onward, water resources development was promoted in full scale with the Ministry of Construction as its foundation. In 1961, the first 5-year economic and social development plan was compiled. At the same time, river improvement with an annual length of 289.3 kilometers was promoted and a 4-year water control plan was established.

The River Act, enacted for river management of water control in 1961, has played a leading role in river management and water resources development. Meanwhile, the 10-year Comprehensive Water Resources Development Plan (1966–1975) was established to promote irrigation and water control simultaneously. In particular, a Special Multipurpose Dam Law was enacted in 1966, which assigned the task of multipurpose dam construction to Korea Water Resources Development Corporation, the apparatus to enforce the law.

Introduction of Multipurpose Dams and Implementation of Basin Investigations

The construction of the Seomjingang Multipurpose Dam, the first multipurpose dam in the country, was completed in 1965. The dam's main functions are flood control, hydropower generation, and water supply. In addition, a large-scale basin investigation was conducted that focused on the four major rivers (Hangang, Nakdonggang, Geumgang, and Yeongsangang).

In addition, approximately 190 agricultural reservoirs were built, and construction of hydropower generation facilities started in this period as well to utilize water and reclaimed water for self-sufficient food production, and to secure a power source for industrialization. The construction of Uiam Dam, built exclusively for power generation, was completed in 1967.

10.3.2 The 1970s: Settlement of Comprehensive Water Resources Development

The Four River Basin Development Plan (1971–1981) was launched and linked to the First Comprehensive National Territorial Plan. In addition, a flood control policy was adopted along the four river basins. This was followed by the construction of multipurpose dams. Following the plan, a consistent development policy was adopted along each river basin, such as working on river improvement and the construction of estuary banks. The River Act was amended in 1971 to include the protection of the Vested Water Right. In 1973, according to the 10-Year Water Resource Development Plan, Soyang River Dam was constructed and became the largest multipurpose dam in the Eastern Region. The construction of other multipurpose dams such as Andong Dam and Daechung Dam followed. In 1979, as the first phase of developing the Seoul metropolitan area, a multiregional water supply system was constructed to ensure stable supply of both domestic and industrial water.

10.3.3 The 1980s: Advancement of Comprehensive Water Resources Development

According to the establishment of the Comprehensive Water Resource Development Plan (1981–2001) in 1980, multipurpose dams including Chungju Dam, Imha Dam, Hapcheon Dam, Juam Dam, and Namgang Dam were constructed. In addition, multiregional water supply systems were also promoted in Seoul, the surrounding area, and other regions. At the same time, estuaries in the four rivers were completed. During this period, water use rapidly increased (tripled from 5.1 billion m^3 in 1965 to 15.3 billion m^3 in 1980) as a result of economic development. In addition, 249 agricultural reservoirs were constructed to secure water supply. As the necessity of water quality management became more prominent, the Korean Environment Department was established in the early 1980s. It started working on water quality management in the public water sector.

10.3.4 The 1990s: Application of Environment-Friendly Water Management

Since the Long-Term Comprehensive Water Resources Plan (1991–2011) was established in 1990, small and medium-scale multipurpose dams were built, such as Hoengseong Dam, Miryang Dam, Buan Dam, Boryeong Dam, Jangheung Dam, and Yongdam Dam. In addition, water demand for industrial and urban areas was met through the construction of multipurpose dams (10 dams, around 3.7 billion m^3 scale, and 600 gigawatt-hours of power generation) and the expansion of multiregional water supply systems (26 facilities, 10 million m^3 scale). However, media reports highlighted the incidents of phenol contamination and organic solvents in the Nakdong River, and water quality became a prominent social issue nationwide. In the aftermath of the incidents, the Korean Environment Department was expanded to the Ministry of Environment, and water and wastewater works belonging to the Ministry of Construction were transferred to the Ministry of Environment. In addition, disaster prevention service works were transferred to the Ministry of Government Administration and Interior Affairs (currently the Ministry of Interior and Safety). In 1999, the Basic Plan on River Maintenance was included in the River Environment Plan through the overall revision of the River Act, and environment-friendly construction methods and river maintenance flow concepts were adopted.

10.3.5 The 2000s: Paradigm Shift

During the shift from supply-oriented quantitative development to a diversified qualitative policy focusing on water quality, ecology, and the environment, dam development decreased and the importance of water quality and the environment was emphasized. Accordingly, alternative water resource development increased. The government strove to reach social consensus by operating water-related councils with related ministries, social societies, and private experts. In 2000, the construction of Yeongwol Dam was canceled and the construction of environment-friendly small and medium-sized dams including Pyeonglim Dam, Gunwi Dam, Buhang Dam, and Gampo Dam as well as the redevelopment of Seongdeok Dam were promoted.

10.3.6 The 2010s: Adapting to Climate Change

In 2011, the second revision of the Long-Term Comprehensive Water Resources Plan was conducted to secure water resource for addressing climate change and supporting the water industry. In addition, the Four River Restoration Project and the Gyeong-in Ara Waterway Project were completed. The plan for conservation and utilization of riverside spaces was established by reflecting the opinions of all stakeholders through transparent governance.

10.4 Water-related Organizations and Laws

The Republic of Korea's water management system can be described as centralized and diversified. In its early stages of development, organizations closely related to development and quantitative growth oversaw decision making and implementation. However, as the water management paradigm changed over time, its organizational structure also changed to be able to implement new policies. On 28 May 2018, the Republic of Korea's Parliament approved the revision of three water management laws, resulting in drastic changes to the water management organizational structure of the central government.

To better understand the background and direction of the 2018 restructuring, this section will focus on the organizational structure that existed beforehand.

10.4.1 Organizational Status before 28 May 2018

Central Government Level

In general, the Ministry of Land, Infrastructure and Transport was in charge of water quantity management, whereas the Ministry of Environment was in charge of water quality management. Water has been traditionally perceived as a public good in the Republic of Korea. Hence, it is generally accepted that the government takes responsibility for managing water resources. More specifically, multiple ministries are

Table 10.1: Water-related Organizations, Before Restructure

Ministry	MOLIT	ME	MAFRA	MOIS	MOTIE
Policy	Comprehensive water resources development	Water conservation plan	Agricultural water plan	Disaster prevention plan	Power development plan
Resource Management	▪ River management ▪ Flood control ▪ Reservoir management ▪ Groundwater quantity management	Drinking spring water management	▪ Agricultural reservoirs ▪ Groundwater quantity and quality management in rural areas	▪ Hot springs ▪ Small rivers	
Business	▪ Multipurpose dam construction and management ▪ Multiregional supply system construction and management	▪ Local water (retail) management ▪ Water reuse ▪ Sewage systems	▪ Irrigation water (dam) ▪ Agricultural dam construction ▪ Groundwater development		▪ Hydropower ▪ Small-scale hydropower
Evaluation/ Observation	Hydrological data observation	▪ Drinking water quality ▪ Groundwater quality			

MAFRA = Ministry of Agriculture, Food and Rural Affairs; ME = Ministry of Environment; MOIS = Ministry of the Interior and Safety; MoLIT = Ministry of Land, Infrastructure and Transport; MoSF = Ministry of Strategy and Finance; MOTIE = Ministry of Trade, Industry and Energy.

Source: Author.

engaged in water management, but no overarching control tower that oversees and coordinates functions and businesses exists. The principal roles of each ministry in relation to water management (pre-2018 restructuring) are listed in Table 10.1, and those of public institutes in Table 10.2.

Private Sector

Private sector participation has been encouraged since the early 1990s. Private firms have been particularly active and engaged in the field of wastewater treatment. The number of public sewage treatment plants operated by private companies was 375 out of 528 (71.0%) in 2012, compared to 46 out of 91 (50.5%) in 2001, indicating a rapid increase of 20.5 percentage points.

Table 10.2: Public Institutes Associated with Water Management

Ministry	Institute	Main Responsibilities
MOLIT	Regional Construction Management Office	▪ Responsible for national river management as an administrative body ▪ Five regional offices exist by province ▪ Oversees the maintenance and management of national rivers and develops and implements the action plan ▪ Checks construction status and manages safety of water facilities in the region
	K-water	▪ Responsible for construction, operation, and management of various water development facilities including multipurpose dams, Nakdong estuary bank, weirs, and canal facilities ▪ Mitigates the effects of droughts and floods ▪ Responsible for the construction, operation, and management of multiregional water supply systems ▪ Constructs, operates, and manages sewage treatment facilities when they are government or local government investments ▪ Operates local waterworks under consignment agreements with local governments ▪ Produces and supplies renewable energies such as hydropower and tidal power
MAFRA	KRC	▪ Develops and supplies agricultural water ▪ KRC supplies 524,000 ha and local government supply 254,000 ha of agricultural water for 778,000 ha of irrigated paddies nationwide
ME	Regional Environmental Management Offices	There are four environmental management offices by river basin which are in charge of managing and conserving the environment around its river basin.
	KECO	▪ Responsible for technical assistance and diagnosis of operating waste management systems, installation and operation of waste recycling facilities, and operation and management of environmental pollution monitoring ▪ Develops sewerage policies and support projects, water reuse policies, integrated operation of local waterworks and water networks improvement projects, construction and operation of automatic water quality measurement, and installation of remote water monitoring and control systems
MOTIE	KHNP	▪ Currently operating 10 hydropower plants (Hwacheon, Chuncheon, Anheung, EuiAm, Chungphyung, Paldang, Bosung River, Gangreung, Guisan hydroelectric, and Seomjin River) ▪ In June 2016, the government decided to unify the operations and management of hydropower dams for efficient water management. The hydropower dams managed by KHNP will be operated in conjunction with K-water's multipurpose dams in terms of discharge quantity and dam water level.

ha = hectare; KECO = Korea Environment Corporation; KHNP = Korea Hydro & Nuclear Power Corporation; KRC = Korea Rural Community Corporation; MAFRA = Ministry of Agriculture, Food and Rural Affairs; ME = Ministry of Environment; MOIS = Ministry of the Interior and Safety; MoLIT = Ministry of Land, Infrastructure and Transport; MoSF = Ministry of Strategy and Finance; MOTIE = Ministry of Trade, Industry and Energy.

Source: Author.

Table 10.3: Water-related Laws

Law	Legal Context	Ministry
Framework Act on the National Land	To contribute to the sound development of the national land and the improvement of the national welfare by providing for fundamental matters concerning the formulation and implementation of plans for and policies on the national land	MOLIT
River Act	To manage rivers properly and contribute to the promotion of public welfare by providing for the matters on designation, management, use, conservation, etc. of rivers with the objective of increasing benefits from river use, nature-friendly maintenance and preservation of rivers, and preventing damage caused by the river flow	MOLIT
Groundwater Act	To contribute to the promotion of public welfare and the growth of the national economy by prescribing the matters concerning appropriate development and utilization of groundwater and efficient preservation and management thereof, aiming for the proper development and utilization and preventing the groundwater from the pollution	MOLIT
Act on Construction of Dams and Assistance, etc. to Their Environs	To rationally develop and use water resources and promote the development of the national economy by providing for matters regarding the construction and management of dams, the revolving investment in costs for the construction of dams, environmental measures following the construction of dams, and support for residents in the areas adjacent to dams	MOLIT
National Land Planning and Utilization Act	To promote public welfare and to upgrade the quality of people's livelihoods by providing for matters necessary for the formulation, implementation, etc. of plans to utilize, develop, and preserve national land	MOLIT
Urban Development Act	To promote planned and systematic urban development, create a comfortable urban environment, and promote public welfare by prescribing matters necessary for urban development	MOLIT
Framework Act on Environmental Policy	To ensure all people have the same rights to enjoy healthy and pleasant lives by preventing environmental pollution and environmental damages and by managing and preserving the environment in a proper and sustainable manner through defining the right and duty of citizens and the obligation of the state with regard to environmental preservation, and determining the fundamental matters for environmental policies	ME
Water Supply and Waterworks Installation Act	To improve the public sanitation and thereby contribute to the improvement of living environments by means of the development of a comprehensive plan for water supply and waterworks installation and, at the same time, the appropriate and reasonable installation and management of waterworks	ME

continued on next page

Table 10.3 *continued*

Law	Legal Context	Ministry
Sewerage Act	To contribute to the sound development of local communities and the improvement of public hygiene and to preserve the quality of public waters through proper treatment of sewage and foul waste by providing for standards, etc. for the installation and management of sewerage systems	ME
Water Quality and Aquatic Ecosystem Conservation Act	To prevent people's health and environment from being exposed to any harm and danger caused by water pollution and to properly manage and preserve water quality and aquatic ecosystems of the public waters, including rivers, lakes, and marshes, etc. in order to enable people to enjoy benefits accruing from measures, and hand down such benefits to future generations	ME
Rearrangement of Agricultural and Fishing Villages Act	To improve and develop agricultural infrastructure, living environments of rural communities, rural tourism and resort resources, and marginal farmland, etc. in an integrated and systematic manner, to raise the competitiveness of the agricultural and fisheries industries and facilitate the improvement of living environments of rural communities in order to contribute to the construction of modernized rural communities and balanced national development	MAFRA
Small River Maintenance Act	To prevent disasters and to contribute to the improvement of the living environment, by providing for matters necessary for the maintenance, utilization, management, and conservation of small rivers	MOIS
Countermeasures Against Natural Disasters Act	To prescribe necessary matters concerning natural disaster prevention or recovery and other countermeasures against natural disasters, in an effort to preserve the national land and to protect the lives, bodies, and properties of people as well as key infrastructures from disasters caused by natural phenomena, such as typhoons and floods, etc.	MOIS
Framework Act on the Management of Disasters and Safety	To establish the disaster and safety control system of the state and local governments, and to prescribe the matters necessary for the prevention of, preparation and countermeasure against, and recovery from disasters and safety controls, in order to preserve the national land against various disasters, and to protect the lives, bodies, and properties of people	MOIS

MAFRA = Ministry of Agriculture, Food and Rural Affairs; ME = Ministry of Environment; MOIS = Ministry of the Interior and Safety; MoLIT = Ministry of Land, Infrastructure and Transport; MoSF = Ministry of Strategy and Finance; MOTIE = Ministry of Trade, Industry and Energy.

Source: Author.

Water-related Laws

Before the restructuring, many water-related laws (Table 10.3) were enacted and operated by the country's four major water-related ministries (Ministry of Land, Infrastructure and Transport; Ministry of Environment; Ministry of Agriculture, Food and Rural Affairs; and Ministry of the Interior and Safety) and local governments. Due to multiple actors being involved in water management, the challenge was that lack of ministerial cooperation may result in policy inconsistency and inefficiency.

As climate change has become more severe and the frequency and strength of floods and droughts increased, an awareness of the quantitative and qualitative management of water resources has increased. There has been criticism in the Republic of Korea on the subdivision of laws and administrative laws, of which there are 20 and 47, respectively, by ministry. This resulted in the overlapping of plans and created problems as regards effective use of budgets. Furthermore, the disconnection between qualitative management policies and quantitative management policies resulted in failure of comprehensive management of watershed environments and ecosystems. Without the consideration of water quality, ecosystems, and demand management, sustainable supply and effective disaster management were impossible. This was especially so because optimal operations limited the consideration of water quality and quantity by river sections due to the dry stream phenomenon.

10.4.2 Rearrangement of Water Institutions on 28 May 2018

As mentioned earlier, water management in the Republic of Korea involves the Ministry of Environment (local waterworks and wastewater treatment), the Ministry of Land, Infrastructure and Transport (dams, multiregional waterworks and rivers), and the Ministry of Agriculture, Food and Rural Affairs (agricultural water).

As a result, there are some side effects such as the duplication of construction and management between government departments, waste of budget, and overlap of regulations. For a long time, there has been a need for unification of water management work and management of integrated water resources.

On 28 May 2018, the National Assembly finally passed the revised bill of the Government Organization Act and established the Water Management Basic Act. The amendments to the Government Organization Act included the transfer of duties related to conservation, utilization, and development of water resources in the Ministry of Land, Infrastructure and Transport, except river management, to the Ministry of Environment. The measures to unify a large part of the water management work centered on the Ministry of Environment are expected to mitigate inefficiency and strengthen water management capacity through the integrated management of water quantity and quality.

The Framework Act on Water Management regulates basic concepts of water management and aims to sustain the water cycle system through securing water supply, conserving the water environment, and preventing water disasters such as droughts and floods, and finally to contribute to improving the quality of life of the people. In addition, it regulates the setting up of the water management committee, which will establish the basic principles of water management, such as water as a public good, water cycle, ecological environment conservation, watershed management, and integrated water resources management, and deliberate and make decisions on important matters regarding water management.

According to the act, a water management committee will be set up at the national and basin levels. Every 10 years, the Ministry of Environment should establish a basic water management plan after discussing with the heads of the relevant central governments and the chairs of the basin management committee.

The Framework Act on Water Management is of great significance, because it acts as the supreme law related to water, thereby resolving conflicts and related disputes. In particular, it is expected to be able to suppress wasting budget, and to regulate the conflicts or different interests among the diverse ministries that manage respectively water quantity, water quality, agricultural water, and water-related disasters. In this context, the water management functions of the government have been transferred from the Ministry of Land, Infrastructure and Transport to the Ministry of Environment.

In order to streamline water management and resolve water-related issues such as water disasters, the National Water Management Committee and Watershed Management Committee are to be established and operated. The Ministry of Environment plans to integrate and manage the local water supply system on a watershed basis. In addition, it plans to eliminate droughts by developing and supplying water resources tailored to local conditions (for example, sewage reuse, leakage reduction project). It also plans to strengthen forecasts and response to water disasters such as urban flooding.

10.5 Water Services

Multiregional water supply systems operated by K-water and local water supply systems operated by local governments are two main water services in the Republic of Korea (Table 10.4). K-water supplies water

Table 10.4: Water Services

Classification	Content
Multiregional water supply system	General waterworks that provide raw or processed water to no less than two local governments
Local waterworks	General waterworks, excluding multiregional water supply systems and village waterworks, which are operated by local governments to provide raw or processed water to their own residents, their neighboring local governments, or their residents.

Source: Author's translation based on the definition clause of the law.

abstracted from dams or national rivers, while local governments supply water abstracted from its own water sources or by a multiregional water supply system or dam.

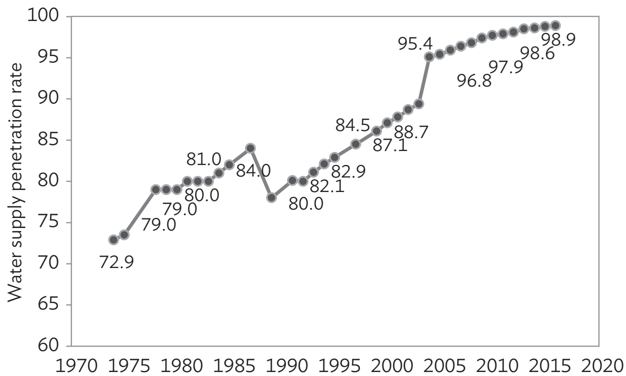
10.5.1 Dam Water

K-water processes water abstracted from multipurpose dams and water supply dams that it manages to meet the types of water (raw, settled, and purified water), and then supplies the water to local governments or industries. From there, local governments take the responsibility of channeling water to households. As of 2014, K-water operates 35 multiregional water supply systems. The Seoul metropolitan area utilizes 8.285 million m^3 per day, which is 60.2% of the total facility capacity (13.860 million m^3 per day). In terms of water supply, 52.9% of the total national water supply is consumed in the Seoul metropolitan area.

10.5.2 Local Waterworks

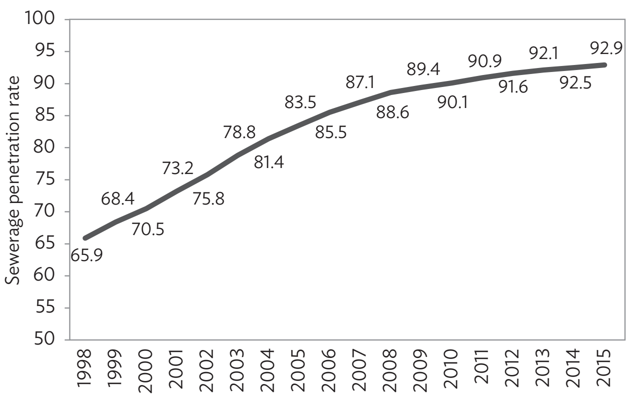
Local waterworks are managed by local governments to supply domestic and industrial water either by directly abstracting water from their own water sources such as local rivers or by receiving raw or purified water from a multiregional water supply system. As of 2017, the Republic of Korea has 161 local waterworks operators (7 metropolitan cities, 1 metropolitan autonomous city, 1 special self-governing province, 74 cities, and 78 districts) and 1 multiregional water supply system business operator (K-water). Figure 10.5 shows that 98.9% of the population had access to clean water through water supply systems as of 2016, and Figure 10.6 shows that 92.9% had access to sewage facilities in 2015.

Figure 10.5: Water Supply Penetration Rates
(%)



Source: Waterworks statistics, each year, Ministry of Environment.

Figure 10.6: Sewerage Penetration Rates
(%)



Source: Waterworks statistics, each year, Ministry of Environment.

10.6 Water Pricing

10.6.1 Economic Instruments

Several water tariffs and user charges exist in the Republic of Korea. Each organization imposes water tariffs or user charges under the existing laws (Table 10.5).

Table 10.5: Water-related Revenue Sources at the National Level

Organization	Revenue
MOLIT	Income from rivers (national rivers)
ME	Discharge dues, environment improvement charges (water pollution), water quality improvement charges, charges for release of pollutants in excess of the total quantity, and water use charge
Local governments	Local water tariff, wastewater tariff, income from rivers (local rivers), groundwater utilization charge, local resource, and facility taxes
K-water	Dam water tariff, multiregional water tariff

ME = Ministry of Environment; MOLIT = Ministry of Land, Infrastructure and Transport.
Source: Author's summary.

10.6.2 Ministry of Land, Infrastructure and Transport

The fee for the use of river water is levied on river water users by local governments according to Article 50 of the River Act. In other words, local governments have a mandate to collect and execute the fee for the use of national river water. Other fees such as occupancy fees, licensing fees, and receipts gained from the site of a desolate river are also levied for occupying riversides and so forth (see Tables 10.6–10.8 for revenue sources at different levels).

For the construction of multipurpose dams, the associated financial burden is shared pro rata according to the benefits and purpose between K-water and the government. In terms of the construction cost of multiregional water supply systems, the government's responsibility has declined to 30% since 2007 (Table 10.9).

Table 10.6: Water-related Revenue Sources at Local Level

Category	Content
Water and wastewater tariff	The biggest source of revenue is generated from local water and wastewater tariffs that are collected from end users (households), but the financial gap between required expenditure and revenue is significant.
Fees	Fees for issuing certificates and licenses, etc.
Groundwater utilization charge	A groundwater utilization charge is levied when local governments develop their own groundwater sources. It aims to restrain indiscreet groundwater use and pollution while promoting adequate groundwater use and conservation. The charge can be set within the maximum 50% of the water use charge according to the Enforcement Decree and ordinance. Revenue generated from goes to a local government's special account for groundwater management and is to be spent on various activities with regard to groundwater conservation and management, such as exploration, restoration and purification, and the establishment of groundwater management plans.

Source: Author's summary.

Table 10.7: Water-related Revenue Sources for the Ministry of Environment

Category	Content
Water use charge	Based on the polluter-pays principle, the water use charge was enacted for the purpose of preventing pollution near water sources and managing the total amount of pollution. The charge is proportionate to the amount of water used and is included in a water bill. It is determined by a river basin committee and imposed on end users that rely on the four major rivers as their source of water. The collected charges are placed into the river management fund that is to be spent on water quality improvement projects and to support residents in the upstream of a river. The River Management Committee of each river basin is responsible for managing and operating the fund. Water quality improvement projects include financial support for sewage facilities and livestock wastewater treatment facilities, purchase of land in riparian zones for waterfront green space, and support for residents, non-point pollution reduction projects, water resource conservation, and eco-friendly industries.
Discharge dues	Based on the Water Quality and Aquatic Ecosystem Conservation Act, the discharge dues were introduced in 1983 to be levied on polluters with the objective of minimizing damages on water quality caused by water pollutants.
Water quality improvement charge	Water quality improvement charges are levied on spring water manufacturers, drinking spring water import/sales business operators, and other related industries to be spent on conserving public groundwater resources and improving water quality.
Charge for release of pollutants in excess of the total quantity	Polluters are charged for the release of pollutants in excess of the total quantity according to the Act on the Improvement of Water Quality and Support for Residents of the four major river basins.

Source: Author's summary.

Table 10.8: Water-related Revenue Sources for K-water

Category	Content
Dam water tariff	According to Article 16 of the Korea Water Resources Corporation Act, K-water imposes and collects dam water tariffs for supplying domestic and industrial water through multipurpose dams and estuary banks. Considering the costs for construction as well as operation and maintenance of the dams, tariffs are levied in proportion to the amount of water consumed by users.
Multiregional water tariff	According to Article 16 of the Korea Water Resources Corporation Act, K-water imposes and collects multiregional water tariffs for supplying water through multiregional water supply systems. Considering the costs for construction as well as operation and maintenance of the supply system, tariffs are levied in proportion to the amount of water consumed by users.

Source: Author's summary.

10.6.3 Pricing Procedure of Dam Water and Multiregional Water Tariffs

K-water must submit a request to the central government for approval of any tariff changes. Once received, the request moves to deliberation by the Water Tariff Committee. Before the final approval, the Ministry of Land, Infrastructure and Transport should consult with the Ministry of Strategy and Finance, which oversees inflation on the national level in accordance with the Price Stabilization Act. After the restructuring, this role has gone to the Ministry of Environment.

10.6.4 Pricing Procedure of Local Water and Wastewater Tariffs

Local governments decide on water tariffs (retail price) according to the ordinances on water supply and waterworks. Local governors draft a tariff change plan and request for deliberation to the local price committee. If approved, the plan is then put to a vote for approval from the local council and comes into effect accordingly. While dam water and multiregional water tariffs are applied uniformly across the country, local water tariffs vary in 161 local governments.

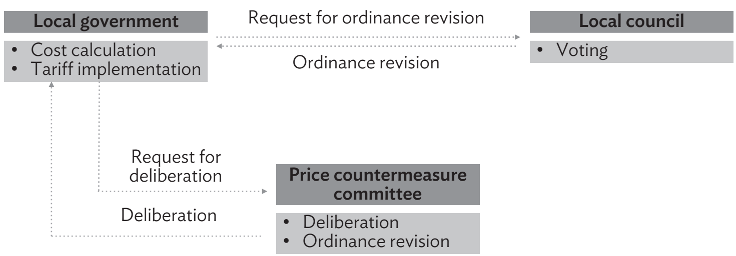
Likewise, any adjustments to the wastewater tariff follow the same procedure. Figure 10.7 shows the process for setting local water and wastewater tariffs.

Table 10.9: Financial Portion for Water Facility Construction

<table>
<tr><th></th><th></th><th></th><th>–1993</th><th>1994–</th><th>1996–</th><th>1998–</th><th>2003–</th><th>2006</th><th>2007–</th><th>2011–</th></tr>
<tr><td rowspan="5">Multiregional Water Supply Service</td><td rowspan="2">All Facilities Except Purification Plants</td><td>Government</td><td>100%</td><td>70%</td><td colspan="3" rowspan="2">100%</td><td>50%</td><td>30%</td><td rowspan="5">Government 30%
K-water 70%</td></tr>
<tr><td>K-water</td><td>–</td><td>30%</td><td>50%</td><td>70%</td></tr>
<tr><td rowspan="3">Purification Plants</td><td>Government</td><td>100%</td><td colspan="2">–</td><td colspan="4">–</td></tr>
<tr><td>Local government</td><td>–</td><td colspan="2">100%</td><td colspan="4">–</td></tr>
<tr><td>K-water</td><td>–</td><td colspan="2">–</td><td colspan="4">100%</td></tr>
<tr><td rowspan="4">Multipurpose Dam</td><td rowspan="2">Construction Cost</td><td>Government</td><td colspan="7">100%</td><td rowspan="4">Pro rata according to benefits</td></tr>
<tr><td>K-water</td><td colspan="7">–</td></tr>
<tr><td rowspan="2">Compensation Cost</td><td>Government</td><td colspan="3">100%</td><td colspan="4" rowspan="2">K-water in charge with partial support from Government.</td></tr>
<tr><td>K-water</td><td colspan="3">–</td></tr>
</table>

Source: K-water document.

Figure 10.7: The Process for Setting Local Water and Wastewater Tariffs



Source: K-water document.

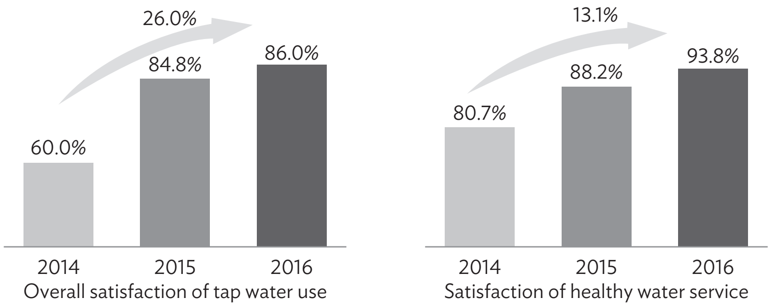
10.7 Case Study: Smart Water Management

10.7.1 Paju Smart Water City

A Smart Water City (SWC) project was conducted in Paju City, a municipality where 390,000 out of a total population of 410,000 are connected to the water supply. Here, K-water in 2014 built a smart water management system that supplies safe water from the source to the customer by improving the stability and efficiency of the supply based on scientific management, using information and communication technology (ICT). The project has enabled the citizens of Paju to check the water quality in their neighborhood and homes in real time using a water quality signboard and a smartphone app. The provision includes a water coordinator service whereby staff directly check the water quality from the tap, and a water doctor service whereby staff directly check the condition of indoor water pipes and clean them. As a result, civil complaints have decreased from 4.5 to 1.3 cases per month, and the average tap-water drinking rate has increased from 1% (before the SWC project commenced) to 41.5% after implementation. Consumer dissatisfaction of tap-water quality has been allayed, and the overall satisfaction of water services was greatly improved (Figure 10.8).

At a time when it is necessary to respond to water crises caused by both rapid economic development and climate change, the Republic of Korea is responding by integrating ICT into water management. Smart water management creates a new paradigm of innovative water management such that it can improve water security and welfare by addressing global water issues and the imperative of sustainable water

Figure 10.8: Performance of the Smart Water City



Source: K-water document.

usage. With those goals in mind, and in partnership with the Asian Development Bank, K-water is providing technical assistance in the application of smart water management to countries such as Bangladesh, India, and Sri Lanka.

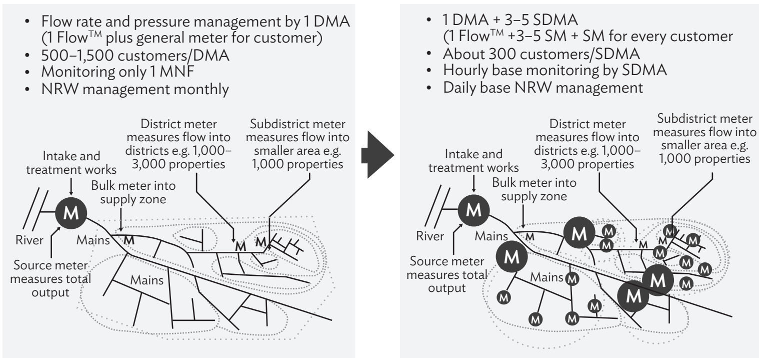
10.7.2 Seosan Smart Water Management

One of the most important tasks for the Republic of Korea's water supply services at present is to minimize the amount of leakage and to supply consistently safe water to users. Smart water management (SWM) technology is therefore essential as it allows operators to use real-time information to cope with such challenges. SWM combines various technologies such as information and communication technology (ICT) systems, Supervisory Control and Data Acquisition (SCADA) systems, smart meters, and other devices to ensure stability and efficiency throughout the network. SWM specifies technologies and creates standards for the overall water circulation system. Examples of applications include Smart Water Grid (SWG), Smart Water City (SWC), Integrated Water Quality Forecasting System (SUIRAN), and Integrated Water Management System (K-HIT).

A smart meter enables the transmission of information concerning consumer tap-water usage measured by time. The use of digital meters and Internet of Things (IoT) technology as an alternative to traditional analog meters allows operators to read meters remotely as well as manage the water usage rate in real time. The smart meter monitoring program developed by K-water analyzes usage, abnormal flow, and

Figure 10.9: District and Subdistrict Metered Areas

Improvements through smart meter technology



DMA = district metered area, MNF = NRW = nonrevenue water, SDMA = subdistrict meters, SM = smart meter.

Source: K-water document.

indoor leakage from the metering information, and provides usage and tariff information to customers through the internet and a mobile app. Previously, flow and water pressure were managed in one district metered area (DMA), but with the application of smart meters, a DMA is divided into 3–5 subdistrict metered areas (SDMAs). Figure 10.9 shows how a DMA was divided into smaller districts.

The management of the daily water flow rate enables quicker responses than before. Smart metering makes it possible to quickly identify leakage locations—immediate detection can reduce leakage from burst pipes and reduce nonrevenue water (NRW)—to quickly correct inaccurate or damaged meters, to reduce supply costs, to improve asset management efficiency, and ultimately to enhance customer satisfaction.

In the case of Seosan City, Boryeong Dam supplies 80,700 m^3 of water per day, sufficient for a population of 157,000. The water penetration rate is 91% and the NRW rate is 16.6%. One specific area in the city, Cha-ri, was operated by two DMAs, and it was difficult to identify and cope with water loss due to the relatively wide supply area. Efforts to reduce loss were nevertheless essential because of drought.

In general, Seosan City has a relatively low NRW rate, whereas the rate of Cha-ri was the city's highest at 32% in 2015 (Table 10.10). Improvements were made by installing smart meters, and nine SDMA systems were built within the existing two DMAs. In addition, NRW

Table 10.10: Nonrevenue Water Comparison, 2015 and 2016, Cha-ri Water Supply Area, Seosan

Nonrevenue Water	March	April	May	June	July	August	September
2015	40.8%	36.5%	37.8%	28.8%	34.4%	26.2%	28.5%
2016	37.5%	26.6%	30.6%	26.8%	29.6%	11.6%	9.8%
Variation rate	↓3.3%	↓9.9%	↓7.2%	↓1.9%	↓4.8%	↓14.6%	↓18.7%

Source: K-water document.

analysis was converted to a daily system, which was previously monthly. Finally, water flow monitoring was expanded from three branches to 12.

After the installation of smart meters, intensive leak detection was carried out on vulnerable sections, reducing flow meter errors. Comparing the DMA flow rate and the total flow rate of the water supply area in Cha-ri resulted in a difference of 430 m^3 per day; inflow meter failures were detected and flow meters were substituted. After analyzing the patterns of both seasonal and hourly customer usage through smart metering, water pressure management is now conducted hourly. Automatic control of the decompression valve through SCADA systems are adjusted according to usage, depending on the season and holidays.

There is now greater flexibility in managing the response times required to address complaints of failure. As a result of installing the first smart metering system in June 2016, an NRW rate of 10% was achieved. As indoor leak detection has improved, so has the NRW rate and customer satisfaction. The control system allows for the analysis of customers' usage patterns according to the time of day. It also provides a "leak suspicion" alarm enabling inspectors to quickly visit a site and take recovery action if a leak is detected. This has resulted in a reduction of approximately 55% of customers' water usage and a consequent reduction in cost to the customer of 70%. Based on the results of operation monitoring over a 2-month period, the net financial benefit is expected to be about 610 million won over the next 8 years (B/C = 2.1) with a 20% improvement in the NRW rate and a 190,000 m^3 per year leak reduction.

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11

Sanitation and Sewerage Management in Malaysia

Dorai Narayana

11.1 Background

Malaysia is often considered a successful example of infrastructure provision in the developing world. Since independence in 1957, policies adopted in Malaysia have resulted in a reasonably good quality of life for the people, supported by holistic urban development. Water supply and sanitation was not left out, and today almost 100% of Malaysians have access to piped water supply and toilets, with safe sanitation. Over the years, piped sewerage has been provided to over 70% of the population. These systems collect black and gray water, and convey it to off-site treatment facilities, which are largely functioning and producing good quality effluent. Of the balance, almost 20% use septic tanks that are designed to proper standards. The remaining population use other on-site systems such as non-standard septic tanks or pits. Not all on-site systems are emptied of sludge regularly, but all sludge collected is properly and safely conveyed to facilities that treat the sludge before disposal.

11.2 Improvements over the Years

Prior to independence, the British colonial government improved sanitation in a few major cities, but the majority of urban areas resorted to open defecation, hanging toilets, buckets, and other primitive and unsatisfactory systems. With urban growth, cities became densely populated, and the predominant reliance on ground water (wells), set the stage for sanitation issues. Waterborne diseases such as diarrhea, cholera, dysentery, and typhoid were common.

Post-independence, local authorities began paying more attention to sanitation. Improper systems such as bucket and overhanging latrines were phased out. Standard septic tanks were introduced and some level of control resulted in reasonably well-constructed septic tanks. At the same time, piped water supply was made available in most urban areas, and flush toilets were introduced in tandem. In the rural areas, sanitation programs provided toilets and pit latrines, with sufficient buffer from drinking water wells. In effect, these developments successfully addressed the public health hazards of improper sanitation at the household level and in the immediate vicinity.

The larger urban areas were at the same time seeing rapid development. A government policy was introduced whereby developers of large housing projects had to build sewerage infrastructure consisting of sewer networks and treatment facilities for their developments. Smaller developments were required to provide properly designed individual septic tanks. This policy resulted in sewerage infrastructure being provided for all new developments. Moreover, it was done without any financial burden on the local authorities. Conversely, it also caused several shortcomings:

1. Urban areas were undergoing large-scale development, and as a result, private developers were building increasingly large numbers of sewerage systems. These systems were not standardized, and varied widely in terms of designs and equipment.
2. There was insufficient capacity in the public as well as the private sector, and the sewerage infrastructure built was often defective in design.
3. Once these systems were completed, they were handed to the local authorities to operate, but they lacked sufficient skilled technical personnel to operate them.
4. Private developers usually chose the lowest cost options when installing facilities, which often had serious issues, such as being difficult to operate and maintain, and had high operational and maintenance costs.
5. All these led to the sewerage facilities beginning to develop problems, including defects, overflows, and nuisances. Untreated or poorly treated sewage overflows were common.
6. At the same time, the numbers of septic tanks were growing, and, without regular desludging, sludge overflows to drains occurred often.
7. Even when desludging was done, there were no facilities for the proper treatment and disposal of the sludge, and it was usually dumped on land, in rivers, or elsewhere.

Though basic public health aspects of sanitation had been adequately addressed, overall protection of water resources and the environment was far from satisfactory. The root causes of the issues were deficiencies in the regulatory framework, institutional arrangements, capacity, awareness, financial and other resources, and overall management. Matters soon reached a critical situation, resulting in serious pollution of rivers, lakes and coastal areas. Not only were water supply sources being affected, but sewage was polluting recreational and tourism areas. With such a visible impact on the environment, having serious health and economic implications, the government decided that something drastic had to be done.

11.3 The Sewerage Services Act: Federalization and Privatized Concession

While the other infrastructure development in the country was approaching world-class standards, sewerage and sanitation management was glaringly ineffective. It was obvious that the local authorities, if left to manage the sector, would not be able to effect the major improvements that were urgently called for.

In 1993, the Sewerage Services Act was enacted, transferring the power to manage sanitation and sewerage from the local authorities to the federal government. The Federal Sewerage Services Department was designated as the regulator, while a 28-year Concession Agreement was signed with a private entity, Indah Water Konsortium. At a stroke of the pen, the governance, regulatory, and institutional aspects had been addressed.

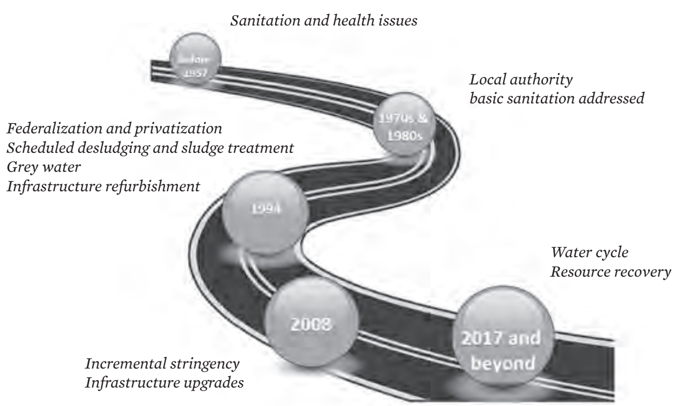
Indah Water was required to provide services in all urban areas, and its responsibilities included:

- Operate and maintain public sewerage systems
- Carry out scheduled emptying of all septic tanks
- Treat and dispose of sludge
- Refurbish all sewerage infrastructure to operating condition
- Planning for expansion of coverage through construction of new sewerage facilities

It is to be noted that this drastic move was carried out with little preparation on the ground, especially stakeholder engagement. It was a largely a top-down approach. However, there was little resistance from the local authorities and state governments, who were happy to give up what they saw as a problematic role.

With the federalization and privatization, the country saw spectacular improvements in sewerage management (Figure 11.1). Unprecedented amounts of funds were invested for the repair, refurbishment, and upgrading of the dilapidated sewage treatment plants. Regulatory control was tightened. Sewerage planning was done systematically. Guidelines and standards were established, and a system to check and approve all new sewerage built by private developers was introduced. This resulted in a vast improvement in the quality of developer-built systems. The government, helped by Indah Water, instituted training and capacity-building programs, and, over the years, many technical and managerial personnel were produced to support the industry. Indah Water's Technical Training Centre offered a complete range of specialized programs, with mock facilities for hands-on trainings.

Figure 11.1: The Malaysian Journey



Source: Blackett and Hawkins (2017).

11.4 The Malaysian Experience: Lessons Learned

Realistic expectation: Coexistence of sanitation systems. Policies and planning philosophies accept that a completely sewer-connected city is unrealistic. Most urban areas will have a hybrid mix of on-site, community, decentralized, and centralized sewerage systems for the foreseeable future. Based on local needs, the respective population ratios served by each may change, moving up from simpler and less effective systems to more effective, sophisticated ones.

Willingness to pay: Perceived value of sewerage and septage services. The privatization exercise was done without adequate preparation of the community. Moreover, sanitation and sewerage were largely public goods, and the users could only perceive private benefits up to a certain point (usually outside the immediate vicinity of the house). Beyond that, users did not see any added value. The benefit was more to the community or environment. As a result, the assumption made in the concession model that the full cost of the infrastructure and services could be recovered from user fees (tariffs) was proven to be not possible.

Although the tariffs were very low, and well within affordability for most Malaysians, the above factors resulted in poor collection of revenues. Moreover, there was little Indah Water could do to enforce payment.

Stakeholder engagement and awareness raising. The above model of cost recovery through tariffs charged on users might have succeeded had there been adequate awareness campaigns, engaging the community and other stakeholders. But it was done abruptly, and most people were at a loss as to why they were suddenly being asked to pay for a largely unseen service, which they had all along assumed to be a part of local government services, for which they were paying property taxes anyway.

Low tariff. The tariff was RM8 ($2) per month per house. The tariffs for commercial premises, industry, and government were much higher, but the domestic customers predominated. As a result, the overall revenue was far lower than required for sustainable operation. The high commercial tariff (to cross-subsidize the domestic customers) was unpopular among the business community, and lobbying by this sector resulted in its downward revision, further worsening the revenue position for the company. In 1999, Indah Water could no longer sustain its business, and was over bought by the Federal Government of Malaysia.

Scheduled desludging. The concession required all septic tanks to be desludged at 2-year intervals. Users were charged a tariff of RM6 ($1.50) per month per house and were entitled to desludging once every 2 years. Indah Water faced many challenges in implementing this:

- **Creating a database.** Local authorities had incomplete data that had to be enhanced through painstaking ground surveys. Using this database, emptying schedules were prepared, and notices issued to households.
- **Tankers.** As part of the privatisation, local authorities transferred their tankers to Indah Water. But these were generally in poor condition, and the company had to acquire new tankers in most areas.

- **Developing a sludge management strategy.** Up till then, most local authorities had no proper sludge treatment or disposal sites. Indah Water came up with a sludge management strategy, with co-treatment in oxidation ponds and other sewage treatment plants as an immediate strategy. Meanwhile, suitable sites were identified for treatment/disposal, and approvals sought from the environmental regulators.
- **Technologies.** In the beginning, simple, basic systems such as trenching were adopted. Gradually, these were replaced with drying beds, mechanical dewatering facilities, and regional sludge treatment plants. Since many sewage treatment plants (STPs) were available, with adequate capacity, the liquid portion of the sludge was usually co-treated with sewage in these STPs.

With all the above efforts by Indah Water, the success rate of desludging achieved was still only about 30%. This appears low, but in practice can be considered a good achievement, especially because there was not much enforcement assistance by the regulator on households that did not agree to the scheduled desludging.

Synergy with water supply services. With the federalization, sewerage became a federal government function, while water supply was still managed by state governments. The many advantages offered by institutional co-management of water supply and wastewater were therefore lost:

- Water cycle-based management
- Treated effluent reuse possibilities
- Coordinated billing and collection of tariffs

As a response, the Water Services Industry Act was enacted in 2008. This integrated water supply and wastewater management to some extent by creating a single ministry in charge of water, and a single regulator: The National Water Services Commission (SPAN). This enabled policy and regulatory level integration. However, at the operational level, it was still managed by separate entities.

The government has indicated that it intends to decentralize sewerage management, and integrate it with the state water supply companies. This effort has encountered several stumbling blocks, and since 2008, not much progress has been achieved.

Liberalization approach for scheduled desludging. With the passing of the Water Services Industry Act, it became the responsibility of house-owners to ensure their septic tanks were desludged regularly (now every 3 years). They could call Indah Water or any licensed tanker operator to carry out the desludging. This worsened the situation because Indah Water stopped scheduling the desludging, and the regulator was not in a position to monitor and enforce the scheduled emptying.

11.5 Federalization and Privatization: An Overall Success

Indah Water today provides services in most urban areas of West Malaysia. A total of more than 24 million people use its services, which consist of both sewerage and desludging services. The company has built up expertise ranging from managerial and technical to skilled operators. With a workforce of more than 3,500 supported by numerous contractors and vendors, it manages a sewerage network of over 18,000 km of sewers, more than 7,500 sewage treatment plants and about 65 sludge treatment facilities. This makes the company a powerful repository of know-how and expertise related to sanitation and sewerage.

The outlook for the company is in question. Tariffs have remained stagnant since the company was established, and operational and other costs have ballooned, resulting in sustained losses. However, the company has performed well in other aspects: key performance indicators relating to operational performance, effluent compliance, complaints, and redressal have improved remarkably.

11.5.1 Challenges Faced

Indah Water faced serious challenges from the outset:

1. As mentioned, the community had not been adequately prepared to pay for sewerage and desludging services. Although the tariff was very low, and certainly affordable to most Malaysians, people did not understand why they had to pay it. Indah Water had little recourse to recover unpaid bills other than legal action, which was prohibitively expensive.
2. The scheduled emptying of septic tanks, while well intended, achieved only limited success, again due to poor prior preparation of the ground for this service. Most people did not see why they had to empty their septic tanks, when they were apparently not facing any issues. There was also little enforcement by the regulator, which could have helped the company achieve a better result.
3. The basis of the concession, whereby the tariff would cover full capitalization and operation cost recovery, was flawed, and the tariff proved to be grossly inadequate.

By 1999, Indah Water ran into serious financial problems and federal government was forced to buy it out. Through sustained campaigns, the company has managed to improve collection, but still incurs losses of a few hundred million Malaysian *ringgit* every year, and the government covers this gap through a subsidy.

11.6 Achievements

The apparent failure of the privatization should not overshadow the many achievements that the sector saw in the period. Moreover, the learning has spurred the government to move ahead, building on the momentum achieved so far:

1. The robust regulatory framework that has been built up is supported by adequate legislative empowerment and institutional arrangements with clear roles.
2. With adequate investment allocation, aging and malfunctioning systems were repaired and refurbished.
3. Scheduled emptying regimes have been established, although only limited success was achieved. Proper emptying, transport, and treatment/disposal practices have evolved, and numerous sludge treatment facilities already exist.
4. Systematic guidelines and controls on developer-built infrastructure have ensured good quality infrastructure.
5. Catchment planning for sanitation and sewerage has guided government investment, ensuring appropriate allocations of funding for CAPEX.
6. Although the initial stakeholder engagement and awareness and education campaigns were lacking, since then, sustained efforts have resulted in good awareness among the community on the importance of good sanitation and sewerage management.
7. A huge pool of talent: managerial, technical, and skilled operators, has been created, to support the sustained progress on the sector.

The major factors which contributed to the success were the following:

- The federal government began driving the whole process, with a strong political push.
- Standardized and uniform policies were applied, operationalized through laws, guidelines, and procedures.

- The various players and stakeholders (government, regulator, operators, developers, etc.) had their respective roles and responsibilities clearly defined.
- With the federal government driving the sector, substantial funding allocation was made available to boost investment in infrastructure.
- A major role was given to the private sector, with Indah Water being awarded the concession. The company, which operated with expert foreign partners, helped develop guidelines, operating instructions, and other systems.
- Technology was introduced in a phased manner, allowing for capacity to develop in tandem.
- There was effective self-monitoring by the company, complemented by stringent oversight by the sector regulator, SPAN, as well as the Department of the Environment.

However, some issues lingered:

- The approach to federalize the sector brought quick and uniform results. However, in the process, state and local governments had little or no role, despite being key stakeholders.
- While sanitation and sewerage became federal government matters, water supply was a state government responsibility. Valuable synergies between water supply and sewerage management were lost.
- The privatization model was based on recovery of the whole CAPEX and OPEX from the tariff. This was unsustainable, and led to huge losses for the private company. It turned out that tariffs had to be substantially higher even to cover operational costs.
- Government investment in sewerage infrastructure lags far behind urban development. Private developers are still the main investors in sewerage infrastructure, and coordination between private and government infrastructure development has proved difficult, resulting in wasteful investment in many cases. Moreover, the developer-led infrastructure development resulted in large numbers of STPs being built, many of which were small and unviable, leading to operational issues.
- The thrust thus far has been to solve the pollution issue, but opportunities for resource recovery (effluent/sludge biosolids reuse and energy recovery) were not considered.

11.7 What Next?

In the decades since independence, Malaysia has made meaningful improvements in the way sanitation and sewerage is managed. Infrastructure has both expanded in terms of coverage and improved. Strong regulatory and institutional structures have been put in place, with clear roles, empowered through enabling legislation. Technical and management capacity has been hugely enhanced; over the years, public awareness has also improved. Malaysia is now ready to address the remaining shortcomings, deciding the most appropriate way forward. Among the thrusts for the sector in the coming years will be the following:

- Primary objectives will remain to protect public health and protect water resources. In addition, secondary objectives will aim to provide nuisance free living space.
- Resource optimisation, reuse and recovery will be given priority.
- CAPEX and OPEX required for sustainable management will be sourced through innovative public and private investment
- Focus will be on "appropriate waste management strategies", considering local needs.
- Considerations of whole life cost, low-energy systems, standardization, and low carbon footprint will be included.

These are all thrusts that have been incorporated in the National Sewerage Planning Policy and Strategy, which will form the basis of the National Sewerage Development Plan. It is envisaged that this will take the country's sanitation and sewerage development into the future.

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12

Institutional Mechanisms for Sustainable Sanitation: Lessons from Japan for Other Asian Countries

Kazushi Hashimoto

12.1 Introduction

Even though access to sanitation facilities has improved in the urban areas of many Asian developing countries, the pollution of public water bodies remains a serious problem. One of the causes of water pollution is improper decentralized wastewater management. Most urban residents in Asian developing countries use septic tanks, many of which are improperly installed, sometimes making them inaccessible for desludging. Although sludge management is essential for any kind of wastewater treatment, the type of desludging for septic tanks in developing countries is mostly "on-call," which is not reliable. Regular desludging is the first step for decentralized wastewater management, which is good not only for household septic tanks but also for packaged aerated wastewater treatment plants (PAWTPs, or *johkasou* in Japanese) or similar facilities already widely used by non-household users (commercial buildings) in Asian developing countries. The proper treatment and disposal of the collected sludge is also essential. However, the development of sludge treatment facilities is far behind that of sewerage systems in developing countries.

This is in contrast with Japan, where more than 1,000 night soil treatment facilities were built in the 1950s and 1960s, prior to the nationwide development of sewerage systems that started in the 1970s. The incidence of waterborne diseases in Japan was virtually eliminated by 1970. This was attributed to the rapid diffusion of both piped water supply systems and night soil treatment facilities. In the 1960s and 1970s, an older PAWTP type, which treated only black water, was diffused widely among citizens who wanted to install flush toilets as a symbol of modern life but did not want to wait for sewerage system development. From the 1980s, however, the pollution of public water bodies caused by untreated domestic wastewater became highly visible and was attributed to delays in sewerage system development and to the poor performance of the old-type PAWTPs, which released untreated gray water into the environment. To improve the situation, sewerage system development was accelerated, a new type of PAWTP that could treat both black and gray water was developed, and a comprehensive reform of decentralized wastewater management was introduced, with the promulgation of the PAWTP Act (*Johkasou* Act) in 1983. Under the act, the legal basis for manufacturing, installing, maintaining, inspecting, and cleaning (desludging) PAWTPs became clearly defined. To translate these measures, the act specified the responsibilities and duties of users, the central government, municipalities, PAWTP operators, inspectors, desludging businesses, and training institutions. Accordingly, a system of state certifications for installation workers and maintenance operators was created.

The management of decentralized wastewater treatment facilities had been a neglected issue in Asian developing countries until 10 years ago. Recently, its importance has been recognized, and in a few countries and cities, namely India, Indonesia, Malaysia, the Philippines, Hai Phong City (Viet Nam), and Manila City (the Philippines), sludge management for septic tanks is being strengthened. But the problems of unregulated or too few desludging operators persist in many Asian developing countries (Araral 2010). The performance of unregulated desludging vendors is poor, and there are many reports of the illegal disposal of sludge into rivers. Improper operation and maintenance of the decentralized wastewater treatment systems (also known as DEWATS) of commercial buildings due to the lack of human resources is another issue to be urgently addressed.

This study explains the evolution of Japan's decentralized wastewater management system and extracts elements that may be useful in developing countries, including those that use technology other than PAWTPs. These elements are the following:

1. the establishment of a qualification and training system for decentralized wastewater treatment facility installation businesses;
2. the introduction of a regular desludging system;
3. the establishment of a qualification and training system for desludging business/workers; and

4. the establishment of a qualification and examination system for operators of PAWTPs or similar facilities mainly targeted for non-household users.

The establishment of these systems would not consume excessive government resources but would require substantial administrative work. Political support would be essential, since establishing them would affect the relationships between citizens, administration, and sanitation workers. The reward for such efforts would be better decentralized wastewater management systems and the creation of job opportunities, which are badly needed in developing countries. In Japan, nearly 200,000 professionals are working for the betterment of decentralized wastewater management systems.

12.2 Current Situation of Decentralized Wastewater Management in the Urban Areas of Asian Developing Countries

12.2.1 Water Pollution Caused by Improper Decentralized Wastewater Management

Water Pollution in Asian Developing Countries

While industrial economies in Asia have improved their public water bodies in recent years, most Asian developing countries have not, and some have experienced a severe deterioration. In Indonesia, 70%–80% of the major rivers are seriously polluted (Water Environment Partnership in Asia 2018).

Improvement of Access to Sanitation Facilities Does Not Mean Improvement of the Aquatic Environment

The pollution of public water bodies is serious, particularly in the urban areas of Asian developing countries, where the coverage of centralized wastewater treatment systems remains low (Araral and Wu 2016). Although the percentage of residents in Jakarta with access to improved sanitation facilities has reached 87% (2% to sewer systems, 85% to septic tanks), the rivers in the city, in which the average biochemical oxygen demand (BOD) level is 61 milligrams per liter (mg/l), have become natural sewers (JICA 2012). Similar situations can be seen in many Asian urban areas. It is apparent that the increase in access to improved sanitation facilities does not necessarily lead to the improvement of the aquatic environment.

Improper Decentralized Wastewater Management as a Cause of Water Pollution

Water pollution in Asian developing countries may be attributed to: (i) the low treatment efficiency of septic tanks, though they are widely used as household decentralized wastewater treatment facilities; (ii) the large number of septic tanks treating only wastewater from toilets (black water) but not miscellaneous wastewater (gray water), which contains a higher pollution load and is discharged without treatment; or (iii) the improper management of the sludge generated in household septic tanks and in non-household individual wastewater treatment plants.

12.2.2 Prevailing Decentralized Wastewater Treatment Systems with Poor or Variable Performance

Poor Effluent Water Quality of Septic Tanks

Information on the effluent water quality of septic tanks, which are widely diffused in Asian developing countries, is limited. However, JICA's water quality testing of septic tanks in Jakarta indicates that their average effluent water quality is poor (BOD of 200 mg/l, chemical oxygen demand of 530 mg/l) (JICA 2012). There are similar testing data for Viet Nam (Ha Noi) (Harada, Dong, and Matsui 2008) and India (Kazumi 2014) that provide similar figures. We can consider that because of the current lack of sludge management with regular desludging systems, even the inherently insufficient performance standards of septic tanks are not being achieved.

Limitation of Anaerobic Decentralized Wastewater Treatment Systems

In a few countries, improved versions of anaerobic-type wastewater treatment facilities, such as BORDA's DEWATS, have been introduced. Although the effluent quality of these facilities has been improved to some extent from that of septic tanks, they do not comply with the new and recently revised water quality standards of the countries where they have been installed. For example, the effluent water quality of DEWATS installed under community-based sanitation programs (known as SANIMAS) in Indonesia has a BOD of approximately 50 mg/l, total suspended solids of 40 mg/l, and ammonia (NH4-N) of 50–60 mg/l, which met the standards of Indonesia at the time of installation (2011), but not those of neighboring countries (the Philippines and Malaysia) (Kerstens, Legowo, and Hendra Gupta 2012). It is not possible to meet Indonesia's new effluent water quality standard, which was revised in 2016 to a BOD of 30 mg/l, total suspended solids of 30 mg/l, and ammonia of 10 mg/l.

12.2.3 Improper Installation of Decentralized Wastewater Treatment Systems Such as Septic Tanks, Which Are Sometimes Inaccessible for Desludging Operations

Inappropriate Installation of Existing Sptic Tanks

Many septic tanks in old houses in Jakarta were installed underneath the floor in areas such as the kitchen without access covers, seemingly without any consideration for desludging. In some cases, since the elevation of the house floor against the road surface is not sufficient, it is difficult to discharge the septic tank effluent into the street drain, meaning it is inevitably discharged underground, causing groundwater pollution. Similarly, septic tanks installed inside without access covers for desludging can be generally seen in many Southeast Asian countries other than Indonesia. In Hai Phong City in Viet Nam, it is reported that plastic covers are being installed on access holes by workers of the Drainage Corporation (the desludging entity) after septage removal (Water Environment Partnership in Asia 2013).

Points of Attention for the Installation of Decentralized Wastewater Treatment Facilities

Decentralized wastewater treatment facilities must be installed in a way that is accessible for maintenance, including desludging. Piping to connect them to toilets and street drains must be conducted properly. The elevation of the installation site is also important so that the effluent can be discharged to the street drain by gravity.

Necessary Regulatory Framework for the Appropriate Installation of Decentralized Wastewater Treatment Facilities

In some newly built houses in Jakarta, the septic tank is installed outside the house and facing the street, which is convenient for desludging and enables the effluent to discharge into the street drains. The city administration has environmental impact assessments and a building permission system that checks large buildings' wastewater management; however, such checks are not conducted for individual houses.

It is essential for the decentralized wastewater treatment facility installation business to have the correct knowledge on all the points of attention for the installation works, including the selection of proper locations. Accordingly, technical standards for installation, a qualification system for the installation business, and a training system for installation workers are essential.

12.2.4 Lack of Sludge Management

Importance of Sludge Management in Decentralized Wastewater Management

Any wastewater treatment facility, regardless of whether it is a septic tank, a DEWATS, or a PAWTP, generates sludge. Unless sludge is properly and regularly removed, its intended treatment performance will not be attained, and it will become a pollution source itself. The volume of generated sludge is larger in aerobic systems than in anaerobic systems. In the United States, where 25% of the population uses a septic tank, the Environmental Protection Agency recommends sludge pump-outs every 4 years, but the final decision is left to the users (United States Environmnetal Protection Agency 1999). The United States Agency for International Development (USAID) (2010) indicates that in a regularly desludged system, sludge fills less than one-third of the tank. The Swiss Federal Institute of Aquatic Science and Technology (EAWAG) recommends desludging a septic tank every 2–5 years (EAWAG 2008). In Japan, desludging once a year is a legal obligation for household PAWTP users.

Desludging Currently Conducted in Developing Countries Is "On-Call"

In developing countries, preventive regular desludging has not been conducted, with only a few exceptions. The desludging system mostly used in developing countries is "on-call," in which household owners call vendors only in emergencies when their toilet becomes unusable due to blockages caused by accumulated sludge in septic tanks that have been unmaintained for long periods of time. According to the results of JICA's social survey (JICA 2012), summarized in Table 12.1, around 45% of Jakarta residents replied that their septic tanks had never been desludged or that they did not know when their tanks had been desludged, while 7% replied that their tanks were desludged more than once a year. It may be possible that if a septic tank is larger than the required size for the number of users, it would not cause any inconvenience and blockages would not occur even if the tank is not

Table 12.1: Frequency of Desludging in Jakarta, Indonesia
(%)

Desludging Frequency	Low-Income Level	Middle-Income Level	High-Income Level	Leaders	Share of Total
1. More than once a year	9.0	9.5	4.9	7.3	7.6
2. Once a year	11.4	10.7	11.3	17.2	12.7
2. Once every 2 years	9.8	12.2	12.5	6.5	10.3
4. Once every 3 years	3.7	7.3	10.9	8.4	7.6
5. Once every 4+ years	11.8	15.3	19.6	20.3	16.8
6. Never desludged	46.5	38.5	36.2	32.2	38.2
7. Unknown	7.8	6.5	4.5	8.0	6.7

Source: JICA (2012).

desludged for over 10 years. This may be the case for higher-income users who enjoy flush toilets connected to larger septic tanks. But, even in such cases, the septic tanks would have lost their treatment function and would spread pollutants long before blockages happen. In contrast, most of the house owners who desludged more than once a year were low- or middle-income respondents. This may be explained by the fact that since their septic tanks are smaller than the required size for the number of users, the tanks would fill in a short time.

Correlation between the Frequency of Desludging and the Water Quality of Decentralized Wastewater Treatment Facilities

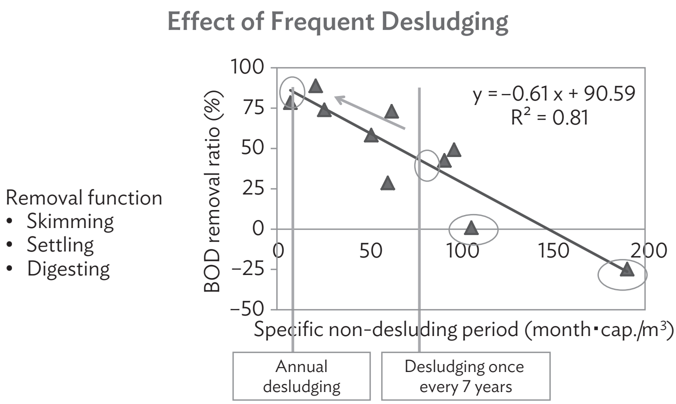
Although there are not many actual data correlating the frequency of desludging and the treated water quality of decentralized wastewater treatment facilities, a test by Harada, Dong, and Matsui (2008) of Ha Noi's water quality indicates that while the pollutant removal rate of septic tanks desludged once a year is 71%, the removal rate of septic tanks desludged only once in 10 years is 0%.

Furthermore, testing data by Tadokoro et al. (1988) on old-type PAWTPs (treating only black water) indicated that their treated water quality deteriorates quickly if they are not desludged within 1 year.

Introduction of a Regular Desludging System

The establishment of a regular desludging system for household septic tanks is the first step for improved decentralized wastewater management since it sets a benchmark for the regular desludging of

Figure 12.1: Correlation between the Frequency of Desludging and the Treated Water Quality of Septic Tanks in Ha Noi, Viet Nam



BOD removal ratio (%) and BOD discharged excluding the effect of dilution (g/L); calculations based on 12,000 mg-BOD/L, 6,000 mg-Cl⁻/L at excretion

- Long non-desludging period increases pollution
- Annual desludging could remove 71% of the BOD load compared to the current conditions

Source: Harada, H. Better Septic Tank Management: Challenges and Remarkable Effects (PPT). Presentation. Kyoto University.

PAWTPs or similar facilities for non-household users. The realistic frequency of the regular desludging of septic tanks needs to be decided with care, taking into consideration the capacity of households to pay the associated fees, since desludging is very expensive. In Malaysia, the desludging frequency was set at every 2 years initially, but it has since been revised to every 3 years.

Proper Disposal of the Collected Sludge

In many developing countries, municipalities do not recognize their responsibility for building and operating sludge treatment facilities, with the result that their development is behind that of sewer systems. Even where facilities exist, their utilization rate remains low, implying that substantial amounts of collected sludge are disposed of in rivers or other water bodies.

On-Site Sludge Management in Asia and the Pacific

Sludge management of decentralized wastewater treatment facilities was a neglected issue until 10 years ago. Recently, even in developing countries, the importance of this issue has been recognized, and, in a few countries and cities, sludge management has been strengthened. In India, Indonesia, Malaysia, and the Philippines, etc., sludge management for septic tanks has become an element of their sanitation and wastewater management policy. For example, in Indonesia, the development of sludge treatment capacity in all municipalities is included in their national 5-year development plan, and pilot projects for regular desludging have been implemented in several cities. Meanwhile, in Hai Phong City and Manila City, the regular desludging of septic tanks has been systematized and implemented for over 10 years. Malaysia started to tackle this issue more than 20 years ago and is undergoing a trial-and-error process. Dumaguete City, in the Philippines, established a regular desludging system in 2007 but reportedly returned to on-call desludging services in recent years (SNV 2015).

Septage Management Is Not an Issue Limited to the Poor

Though septage management is often considered as an issue for the poor, Harada showed how the regular desludging rate is lower for educated groups than for low/middle education level groups. To introduce a regular desludging system, the most crucial factor is how to engage middle-to-high-income households.

12.2.5 Unregulated and Insufficient Numbers of Desludging Operators

Inadequate Performance of Unregulated Desludging Vendors

Even in developing countries, there are demands for on-call desludging. Currently, they are rarely regulated or trained, with the result being inadequate performance. In Jakarta, residents complained that private desludging vendors tend to do careless work, removing only the water content of the tank and leaving the sludge, thus resulting in it becoming full again very soon. There are many reports on the illegal disposal of collected sludge into rivers and other water bodies to avoid disposal fees and long trips to facilities.

Improving Desludging Vendors' Service Is Essential for Effective Non-Household Individual Wastewater Treatment Facilities

The poor quality of desludging vendors is an obstacle for the improvement not only of household septic tanks, but also non-household individual wastewater treatment facilities. If vendors conduct desludging works without proper knowledge of these facilities, which are far more complex and sizable than septic tanks, there is the risk not only of error, but also that the equipment may be broken.

Measures to Improve the Social Status of Desludging Workers Is Also Essential

On the other hand, the social status of desludging workers in developing countries is low, and their income is unstable under current on-call systems. To improve DEWATS in developing countries, measures to improve their social status are also required.

12.2.6 Improper Operation and Maintenance of Decentralized Wastewater Treatment Systems for Non-Household Users

Recent Move toward Tightening Regulations on Non-Household Individual Wastewater Treatment Facilities

The wastewater generated by non-household users, such as apartments, hotels, office buildings, shopping malls, schools, hospitals, and large restaurants, etc. (collectively called commercial buildings) is generally similar to that generated by individual houses, although their volume per square meter is bigger. Therefore, in many countries, stricter regulation is applied to non-household users in comparison to household users. For example, in Jakarta, there are 4,000 commercial buildings for which stricter effluent water quality standards have been applied since 2005, i.e., BOD 50 mg/l, which was revised to 30 mg/l in 2016, and mandatory effluent water quality testing by the municipal environment authority has been introduced since 2005. Consequently, many commercial buildings have replaced their septic tanks with aerobic-type wastewater treatment facilities. Some of them are locally manufactured Japanese-type PAWTPs, while others are imported from countries such as Australia; both are aerobic facilities (collectively called "PAWTPs or similar facilities").

Improper Operation of Individual Wastewater Treatment Facilities of Commercial Buildings in Asian Developing Countries

In Jakarta, 60% of non-household PAWTPs or similar facilities were not properly operated. The majority of PAWTPs or similar facilities use activated sludge processes wherein, if the sludge concentration in the reactor is too high, treatment performance deteriorates. Therefore, to control the density of sludge, Mixed Liquor Suspended Solids monitoring is required. However, there is no evidence that such control work is being conducted. Moreover, since PAWTPs or similar facilities use aerobic processes, the sludge volume is large, requiring desludging at least once a year, twice a year in case of all aeration formula types. Nonetheless, there are facilities that have not been desludged since installation (JICA 2012).

12.2.7 Lack of Human Resources for Operation and Maintenance of Decentralized Wastewater Treatment Facilities

Operating Wastewater Treatment Facilities from Commercial Buildings Requires Expert Knowledge and Experience

For households in developing countries, regular septic tank desludging is the only way to maintain their limited treatment performance. In contrast, PAWTPs or similar facilities used by non-household users feature numerous mechanical parts and devices that require expert knowledge and experience for proper maintenance. Since such human resources are lacking, a system to develop them is required. Once such systems are established, PAWTPs or similar advanced facilities will become usable for households in the future.

12.2.8 Lack or Underutilization of Sludge Treatment Capacity

Necessity to Increase the Capacity of On-Site Sludge Treatment

In order to ensure efficient operations from desludging operators (a desludging vehicle can cover a multiple number of septic tanks or PAWTPs in a day), treatment facilities need to be conveniently located (for example, within 30 minutes' drive). In Japan, for example, about 1,000 treatment facilities were built nationwide. Kumagaya City, a typical mid-size city with a population of 200,000 and an area of 160 km^2, has two treatment facilities. It should be noted that in developing countries, if the distance to the treatment facility is too large, desludging operators will dispose of the collected sludge in nearby public water bodies.

In Developing Countries, Sludge Treatment Capacity Is Inadequate

In developing countries, sludge treatment capacity is far behind that of the sewerage systems. For example, 10 years ago in India, there were no sludge treatment facilities. Indonesia is an exceptional case; in some cities, there are existing sludge treatment facilities, but some are currently not operating. In Jakarta, there are two sludge treatment facilities, both of which are operating, but their utilization is limited. The reason for this may be due to the low coverage of the regular desludging program and the operators disposing the sludge into public water bodies.

Problems of Sludge Treatment Facilities Recently Built in Developing Countries

Recently, a few developing countries have strengthened sludge treatment capacity in line with their policy for improving sludge management for septic tanks. For example, the Ministry of Public Works in Indonesia has established a target to build sludge treatment facilities in all 700 municipalities. As a result, new treatment facilities have been built in a few municipalities and the two existing facilities in Jakarta have been renovated. Sludge from septic tanks and PAWTPs or similar facilities contain a lot of water, and the basic treatment principles are: i) solid/liquid separation; ii) disposal of solid (dried sludge) by landfill, incineration, composting or reuse as building materials or other measures; and iii) wastewater treatment of the supernatant. These principles are not much different from the principles for treatment and disposal of the excess sludge generated in the wastewater treatment plant. But the on-site sludge has two distinct features; it contains more sand and screen residues than in the usual wastewater and has a less homogeneous nature due to its being collected from various sources. For example, in Japan, not only the sludge collected from PAWTPs but also night soil collected from vault toilets, is brought to sludge treatment facilities. Because of these features, the pre-treatment process, in which sand and screen residues are removed and sludge from various sources is stored and agitated before the solid-liquid separation, is important. The "pre-treatment" of many newly built sludge treatment facilities in developing countries is not properly designed, resulting in their poor performance.

12.3 Japan's Decentralized Wastewater Management System

12.3.1 Evolution of Decentralized Wastewater Management in Japan

Achievements in Sanitation: Night Soil Treatment (1950–1960s)

In Japan, vault toilets, which have a water-tight structure and functioned as a temporary storage for night soil, were the most popular historical style of toilet. The night soil stored in the vault toilets in urban houses in Japan was collected and transported to rural areas and used as fertilizer for agricultural production. This night soil recycling mechanism was established well before World War II.

During the rapid economic growth starting from the late 1950s, the traditional night soil recycling systems broke up due to urbanization and the spread of chemical fertilizers, and night soil turned from fertilizer to waste. Meanwhile, sanitary treatment of the increasing night soil in major cities resulted in a serious social problem. To cope with this, municipalities carried out the treatment of night soil and promoted the development of advanced night soil treatment technologies.

In 1953, the government launched a subsidy program for the construction of night soil treatment facilities. As a result, more than 1,100 night soil treatment facilities were built nationwide before the development of sewer systems, which started in the mid-1970s.

In Japan, water-borne diseases (cholera, shigellosis, typhoid) were almost completely eliminated by 1970. This was attributed to the rapid diffusion of both piped water supply systems and the night soil treatment facilities (Ministry of Environment of Japan 2013).

Achievements in Sanitation: The Spread of Flush Toilets (1970s)

During the rapid economic growth starting from the late 1950s, a housing boom occurred, and the demand for flush toilets was high. On the other hand, sewer system development had just started and could not connect to every household. In order to meet the desire for plumbing of those who were unlikely to be connected to the sewer in the near future, PAWTP technology was developed, which could be used for flush toilets in the 1950s and 1960s. PAWTPs became a prominent 1970s measure for the dissemination of flush toilets and sanitation improvement, together with the sewer system.

PAWTPs at the time treated only black water (herein after referred to as “the PAWTP black water only-type”). Entering the 1970s, however, the development of small-scale PAWTPs, which treat both black water and gray water, was undertaken.

From Sanitation to Wastewater Management Based on the PAWTP (1980s to the Present)

From the early 1980s, the pollution of public water bodies caused by untreated domestic wastewater, e.g., eutrophication, became highly visible, particularly in closed water areas. Although legal regulations were already established, the effects of the measures for domestic wastewater did not become apparent at the time because of the delay of the development of public sewerage systems. Especially in areas where the PAWTP black water only-type prevailed, pollution problems in public water bodies was attributed to untreated domestic wastewater (gray water), and improper installation and/or maintenance of the PAWTP black water only-type.

In 1983, the *Johkasou* Law (hereafter referred to as “the PAWTP Law”) was enacted to overcome this situation. In Japan, such laws are usually drafted by the ministry in charge and presented to the parliament. In the case of the PAWTP Law, however, since its contents would affect multiple ministries and no single ministry would write the draft, it was drafted by the parliamentarians supported by the stakeholders of Japan’s decentralized wastewater management system, such as the PAWTP maintenance vendors and desludging operators who deemed it vital for their business. With this law, the legal basis for the installation of manufactured PAWTPs, and their maintenance, inspection, and desludging became clearly defined. To securely translate these measures into reality, the responsibility and duties of PAWTP users were specified and state certification systems were established for both PAWTP installation workers and maintenance operators (Sasaki 2003).

In order to promote the use of PAWTPs that treat both black and gray water, when individuals install them, this facility can be subsidized through a system established nationwide. When the municipalities themselves install the PAWTP in the individuals’ premises as municipal property across their administrated areas, a special subsidy system was launched by the central government in 1998 with the aim of promoting municipalities’ initiatives. The PAWTP Law was amended in 2000 to eliminate the black water only-type and make implementation compulsory when newly installing such facilities.

12.3.2 How Does It Work?

Prevention of Water Pollution Caused by Improper Decentralized Wastewater Management

In Japan, while centralized sewer systems are expected to play a central role for the clean-up of rivers and other public water bodies, decentralized systems, which cover areas where sewer installation is not planned in the near future, are expected to play a supplemental role. However, even when there is no choice other than installing decentralized systems, the structural standards, manufacturing, installation, operation and maintenance, including desludging, of these systems are strictly regulated by the PAWTP Law.

Ensure Good Performance of Decentralized Wastewater Treatment Plants

In Japan, decentralized wastewater treatment plants are standardized. Legally, the PAWTP is the only standard decentralized wastewater treatment plant in Japan. A corporate body that intends to manufacture PAWTPs must receive government approval, which is issued when these proposed plants meets the prescribed design standard. If a manufacturer intends to manufacture a new, non-standardized type of PAWTP, it must be tested by a designated institution.

Ensure Proper Installation of Decentralized Wastewater Treatment Plants

In Japan, those building a new house or building must submit a construction confirmation application prior to the start of construction to the municipality and seek confirmation by the district construction surveyor deployed by the municipality. Usually, this application is made by the house building company on behalf of the house owner. To the building certification application, the type of PAWTP to be installed, together with a copy of the government approval letter, must be attached. If these are satisfactory, the district construction surveyor issues a building permit.

PAWTP installation businesses are subject to registration with the prefectural governor that has jurisdiction over the area where they intend to conduct business, and they must assign an installation worker certified by the Japan Education Center for Environmental Sanitation (JECES) in each place of business.

Ensure Proper Sludge Management, Indispensable for Decentralized Wastewater Management

As mentioned previously, the owner or user of a PAWTP installed in a house or building is, under the PAWTP Law, designated as the "PAWTP (*Johkasou*) Manager". The law mandates these managers to desludge their PAWTP once a year, work that can be entrusted to a PAWTP desludging vendor.

Regulate Desludging Vendors to Ensure Proper Operations while Providing Job Opportunities and Social Status

All the PAWTP desludging businesses in Japan need to obtain the approval of the local mayor. This approval may be for a limited period and is issued if the desludging equipment and the applicant capability conform to the standards prescribed by the Ministry of the Environment (MOE). The applicant must also show no record of violating the PAWTP Law during the 2 years preceding the application.

In order to protect the desludging workers from the anticipated unemployment because of the diffusion of sewerage systems, municipalities are obligated to support their job transfer according to the Act on Special Measures Concerning Streamlining of Domestic Waste Disposal Business incidental to Improvement of Sewerage (1975).

Ensure Proper Operation and Maintenance of Decentralized Wastewater Treatment Systems for Commercial Buildings

The PAWTP Law requires adherence to the maintenance frequency specified by the MOE, which is once every 4 months for small-scale PAWTPs (e.g., a household type), and more frequently for medium- and large-scale PAWTPs, according to the type of treatment process. For example, in case of activated sludge treatment processes, the required frequency is once a week, while for the contact aeration process with screen and flow equalization chambers or flow equalization tanks, the required frequency is every 2 weeks.

PAWTP managers must deploy qualified supervisors when the user population equivalent exceeds 500, and may entrust operation and maintenance (O&M) to a registered vendor. The PAWTP maintenance vendors are required to use certified PAWTP operators in order to engage them in the O&M of these facilities. PAWTP managers must also ensure that their PAWTP receives the inspection of the newly installed PAWTP and an annual inspection for water quality (or the number of times designated by the MOE) by the Specified Inspection Agency designated by the prefectural governor. If it is found that O&M and/or desludging is not done properly, an improvement order will be issued to the O&M vendor and/or to the desludging vendor. The PAWTP manager may be ordered to stop using PAWTP for a period of 10 days or less, if required.

Lack of Human Resources for Operation and Maintenance of Decentralized Wastewater Treatment Facilities

In order to secure the number of technicians required for the decentralized wastewater management, the JECES was established to provide training for professionals in the businesses related to PAWTP in 1966. The following includes details on the certification process for PAWTP workers and operators.

In 1983, the *Johkasou* (PAWTP) Act was established, which stipulated that only the qualified vendors and/or workers can engage in the installation, O&M, and desludging of PAWTPs. In 1984 and 1985, national examinations for PAWTP operators and PAWTP installation workers started. JECES was appointed as the agency for training courses and the agency for the examinations by the PAWTP Act. As for PAWTP desludging technicians, although training and national examination are not legally mandatory, since the desludging vendor is subject to the approval of a municipality, many municipalities give approval on the condition that the applying desludging vendor employs desludging technicians who hold the completion certificate of JECES's training course. Therefore, in reality, only trained professionals can engage in desludging works.

Through the examinations and the training courses, more than 3,000 PAWTP technicians join PAWTP businesses every year. As of 31 March 2016, 213,732 technicians were registered as shown in the Table 12.2.

Activities of the Goto Group

The Goto Group was established in 1963 and is a private company engaged in the maintenance and desludging business of PAWTPs in Kumagaya City, Saitama. The company started its operation with the cleaning of vault toilets and the desludging of PAWTPs, and expanded its operations to the PAWTP maintenance business. The company currently employs 43 staff, 16 of whom hold the certificate of PAWTP operator. A further two hold the certificate of PAWTP installation worker and 14 hold the completion certificate of the PAWTP desludging technician training course.

Table 12.2: Numbers of Certified Technicians Engaged in the Management of the Decentralized Wastewater Treatment System in Japan

Certified Technicians	Number of Registrants	Business Content	Legal Basis
PAWTP operators	80,042	Operation and maintenance	PAWTP Act
PAWTP installation workers	86,595	Installation/construction	
PAWTP technical supervisor	29,794	Management of PAWTP with 501 PE or more	Ordinance of PAWTP Act
PAWTP desludging technicians	16,021	Desludging	
Registered PAWTP inspectors	1,280	PAWTP inspection and water quality examination	
Total	**213,732**		

Source: JICA (2012).

The maintenance of a household-type PAWTP is performed by a single operator and takes 15 minutes. Households pay ¥4,000/work/house as a fee. In Kumagaya City, the frequency is four times a year, one more than the mandated minimum. After maintenance, a checklist is handed over to the household and shared. A PAWTP operator may cover 12 units per day.

The desludging of a household PAWTP is also performed by a single technician taking 15 minutes/house (excluding the time for transportation). The desludging fee is ¥11,000/m^3, equivalent to ¥17,000 for a typical PAWTP for household, the size of which is 1.5 m^3. The required frequency of desludging works is once a year. A desludging technician may cover six units per day.

The service life of the blower for a household PAWTP is about 10 years, if replacement of the failed component is done properly, which costs about ¥8,000 each time. The blower is exchanged with a new one every 10 years, which costs ¥50,000/unit. These costs are paid by the household.

The Goto Group provides maintenance and desludging services not only for household-type PAWTPs, but also for mid-size and large PAWTPs installed for buildings and housing complexes. The company has a group of specialists for the maintenance of mid- and large-size PAWTPs. Maintenance of a mid-size PAWTP installed in a housing complex is also performed by a single operator taking 1.5–2 hours. Operators that cover six buildings/complexes per day meet their target.

As an example, the Goto Group received a contract from the Saitama Prefectural Government for the maintenance and desludging of a mid-size PAWTP installed in a housing complex (about 300 residents) with a capacity of 60 m^3/day. The annual contract is ¥2.1 million. The treatment process of this PAWTP is the contact aeration type, with a required maintenance frequency of every 2 weeks. But, in accordance with the instruction of the prefectural government, maintenance is performed once a week. This housing complex was built in the 1960s–1970s. Accordingly, the PAWTP is considered to have been operating for more than 40 years, but maintains good effluent water quality of BOD 20mg/l or less.

This PAWTP is not only subject to the legal inspection (once a year), but is also subject to a spot check by the prefectural government under the Water Pollution Prevention Act, which regulates all the wastewater treatment facilities whose capacity is 50 m^3/day or more. Therefore, there is no room to pull out. (Notice of spot check will be given 2 weeks in advance. It is impossible to recover the performance of this size PAWTP within 2 weeks if it has not been taken care of properly.)

Secure Sufficient Sludge Treatment Capacity

As stated before, during the 1950s and 1960s, many night soil treatment facilities were constructed throughout the country by local governments. Since the diffusion of PAWTPs, the same facilities are operated as sludge treatment facilities.

12.3.3 Elements of Japan's Decentralized Wastewater Management System Useful for Wastewater Management in Developing Countries

Effluent Water Quality Standards and Selection of Decentralized Wastewater Management System

In order to achieve good effluent water quality, introducing the aerobic-type PAWTP or a similar facility as a decentralized wastewater treatment facility would be required. However, it would increase the capital and operating expenditure, which would exceed the ability of household users to pay, making it difficult to introduce a uniform regulation in developing countries. Therefore, it would be a realistic policy response for governments, on the one hand, to allow the currently prevailing anaerobic-type wastewater treatment facilities, under the condition that their maintenance, including sludge management, is substantially improved. On the other hand, conversion to the aerobic PAWTP or a similar facility should be promoted for non-household users and high-income households if sewer connection is difficult. Accordingly, regulations concerning domestic wastewater, such as the effluent water quality standards, should be different according to the type of user. Otherwise, such effluent water quality standards would end up as a mere target, not the standards which are actually imposed to regulate polluters based on the established value, as is currently the case in many developing countries.

Qualification and Training System for Installation Business of Decentralized Wastewater Treatment Facilities

Improving the decentralized wastewater management would mandate that, when a new house or building is to be built, a municipal construction surveyor checks the facility in the process of issuing building permits, as is the case in Japan. But, the building permits system works only if the decentralized wastewater treatment facilities are standardized by the performance testing system. In developing countries, however, as mentioned earlier, the standardization of decentralized wastewater treatment facilities, particularly those for household users, would be difficult at this moment. Therefore, it would be a realistic policy response that, while the government allows diverse decentralized wastewater treatment facilities, particularly those for household use, it takes measures to ensure the quality of installation of these various facilities via a qualification and training system modeled on that used in Japan.

Introducing Regular Desludging System for Decentralized Wastewater Treatment Facilities

Many countries issue manuals for the maintenance of septic tanks, which indicates their recommended desludging frequency. In many cases, the decision on the timing of desludging is left to the users. As a consequence, in reality, the desludging of septic tanks is conducted only when some troubles such as a blockage happen. If that is the case, the septic tanks would have lost their treatment function, thus spreading pollutants prior to the blockage happening. Therefore, it is essential to establish a regulatory framework in which the timing of the desludging is not left to the users. In Japan, the desludging of PAWTPs is a legal obligation for the users, established as once a year, with the timing controlled by the desludging businesses approved by the municipalities.

It is not clear whether a Japanese-type system would work in developing countries, since the high cost of desludging ($30–$100/unit in Asian developing countries) would become an obstacle. In both Manila City and Hai Phong City, the regular desludging of septic tanks, which has been implemented in a relatively organized manner city-wide for over a decade, is the obligation of the utility (sewer operator) and its cost is recovered by an add-up to the water bill (20% of the water bill in both cities) and by the wide collection from all the household and non-household customers. As the water charge contains a cross-subsidy from non-household users to household users, a similar knock-on effect occurs with the desludging fee. In this way, the average desludging intervals of 5–7 years in Manila City and 4 years in Hai Phong City are achieved. This is a different approach than Japan, but it may fit the actual situation of developing countries.

Qualification System and Training System for Desludging Business and Workers

In Manila City and Hai Phong City, desludging works are performed by water and wastewater operators or sewer and drainage corporations. In many countries, including Japan, however, desludging works of on-site facilities such as septic tanks and PAWTPs are performed by small and medium-sized enterprises. Some of these are micro enterprises, a few of which belong to the informal sector, as also used to be the case in Japan. Consequently, their performance is poor, and they end up conducting illegal activities such as dumping the collected sludge into rivers.

In order to improve this, it would be effective for the government to establish a training system for desludging technicians, and a system in which only the desludging vendors who employ the properly trained technicians are allowed to engage in desludging business so that the authority can regulate them, cultivate their professionalism, and raise their social position.

Qualification System and Examination System for Operators of PAWTPs or Similar Facilities for Non-Household Users

Although qualifications such as those for engineers or graduates from an engineering university are not necessary, it is desirable that technicians for PAWTPs or similar facilities attend a professional training course and pass an official examination, and it would thus be good policy for developing nations to ensure such a system monitors skill levels. As practiced in Japan, if the cost of the training and of the examination is paid by the trainees or the companies for which they work, they would become more serious and the sustainability of the training/examination system would be secured.

In addition, the penalty on the non-household users who fail to engage qualified operators for their PAWTP or similar facility must be strengthened.

Development of Proper Sludge Treatment Facilities

In many developing countries, the development of on-site sludge treatment facilities trails the development of sewer systems. For these countries to improve decentralized wastewater management, its development must be accelerated. In reality, some recent facilities built in developing countries are not operating properly due to inappropriate design.

Japan has a 60-year history of developing sludge treatment facilities. More than 1,000 facilities were built nationwide, and while Japan's sophisticated technologies may not be suitable for developing countries, the accumulated knowledge and experiences on the basic process of on-site sludge treatment, pretreatment, solid-liquid separation, disposal of dried sludge, treatment of supernatant (wastewater treatment) would be useful for developing countries and should be shared internationally.

Among the above-mentioned measures, the establishment of qualifications, training, and an examination system for installation workers, desludging business/workers, and operators of PAWTPs or similar facilities would consume few government resources. However, these would require political will since copious administrative work is required and relationships between citizens, administrations, and sanitation workers need to be augmented. The 1983 PAWTP Law was achieved by politicians backed by sanitation workers. Similar efforts would create better decentralized wastewater management systems and the creation of work opportunities, which are badly needed in developing countries. In Japan, 200,000 professionals are working for the betterment of decentralized wastewater management systems.

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PART III

Policy Perspectives

13

Understanding Behavior Change for Ending Open Defecation in Rural India: A Review of India's Sanitation Policy Efforts

Ankur Gautam

13.1 Introduction

Among the many social and health challenges that India faces, open defecation, which is known to spread diseases like diarrhea that further lead to stunting and malnutrition of children, is one of the most complex, entrenched habit for centuries. To lay out the figures, India, with around 525 million people defecating in the open, ranks as the highest number globally (WHO-UNICEF 2017), with the majority of those practicing open defecation living in rural areas.

The Swachh Bharat Mission (SBM) was launched in October 2014 in realization of this challenge. The scheme has committed approximately $9.4 billion over 5 years, aiming at total elimination of open defecation and provision of basic toilets to every household by 2019. While this government-sponsored scheme was underway, reports of toilets being used as storage started to emerge (Lakshmi 2015). Since the contemporary belief was centered around the notion that people defecate in the open because they do not have toilets, the idea that sponsored construction alone would lead to a reduction in open defecation has not proved to be robust. While demand-generation approaches such as community-led total sanitation (CLTS) feature in the government's policies, the matter of behavior change is more complex. Regardless, at the time of writing, 10 out of 29 states have been declared open-defecation-free

(ODF) and more states continue to make rapid progress with their toilet construction programs and getting themselves the coveted ODF status (Government of India 2017).

While states in India have made rapid strides through the construction of toilets, reports like the one mentioned above continue to emerge, demonstrating states' apathy toward the real problem. Research has pointed that there is difficulty in measuring latrine use and also a need for bringing psychosocial perspectives to generate demand in order to effect sustained behavior change (Lahiri et al. 2017). Yet, news of states achieving the ODF status are heavily advertised.

The objective of this chapter is to inform of India's sanitation policy programming by pointing out gaps in institutional understanding of demand creation, behavior change, and means of measurement and verification. The findings reveal bottlenecks in delivery of India's biggest sanitation program. The chapter also discusses latrine use measurements and provides recommendations for a more robust ODF verification mechanism.

13.2 Methods

The research for this chapter relies primarily on academic and policy literature reviews. From the copious academic literature around sanitation, it was found that most studies focused on toilet construction. Since the purpose of the chapter is to enhance the understanding of toilet use and verification, only studies that looked at latrine "use" in rural India as an outcome were considered for the analysis. In terms of policy literature, the main document reviewed was the national Swachh Bharat Mission–Rural Guidelines, and also the guidelines issued by states, especially those that had been declared ODF at the time of drafting the chapter, although no significant variation compared to the national guidelines was found.

The chapter also includes findings from primary interviews (confidential) conducted by the author in April 2015 with senior government officials implementing the SBM in connection with the evaluation of a Water, Sanitation, and Hygiene multilateral's efforts to complement the efforts of the government in Bihar and Jharkhand, two of the worst-performing states in sanitation coverage in India. The interviews were analyzed by coding under emerging themes.

The review of policy and academic literature, along with coding of the interviews, led to an analysis of main themes and synthesized findings in a narrative. No statistical methods or meta-analyses were required given the nature and scope of the chapter.

13.3 Evidence on Latrine Use and Behavior Change

A randomized controlled trial study (Clasen et al. 2014, p. e645) notes, "increased latrine coverage is generally believed to be effective for reducing exposure to faecal pathogens and preventing disease; however, our results show that this outcome cannot be assumed. As efforts to improve sanitation are being undertaken worldwide, approaches should not only meet international coverage targets, but should also be implemented in a way that achieves uptake, reduces exposure, and delivers genuine health gains". The most common interventions to promote or improve the use of toilets in India have been in the form of subsidies and information, education, and communication (IEC).

Kamal Kar's CLTS approach focusing on "empowering local people to analyse the extent and risk of environmental pollution caused by open defecation" (Kar and Chambers 2008) appears to be the most widely recognized approach for demand generation and sustained use of toilets. The CLTS is a sanitation behavior change intervention that was developed in Bangladesh in the late 1990s (Kar and Chambers 2008). The approach is inspired by a participatory rural appraisal, yet is more forceful in highlighting the disgust associated with open defecation. It is distinct from other approaches due to its emphasis on "shame" and "disgust" to trigger behavioral change (Noy and Kelly 2009). The idea rests on the belief that people would spontaneously abandon open defecation once the disgust and shame are triggered. Dickinson (2008) noted that the "convenience" of latrines, which is often highlighted in CLTS, and the positive perception observed among households in Odisha,[1] "may be key to the longer-term sustainability of sanitation related behaviour change in this area".

Other studies have focused on subsidies to promote household or community toilet construction and use, with interventions taking the form of monetary grants disbursed by the state or central government, or a development agency. The basic premise is that people would like to build toilets but do not have the money or resources to build them. Barnard et al. (2013) conducted a cross-sectional study investigating latrine coverage and use in Odisha where the Government of India's large-scale Total Sanitation Campaign (TSC) had been implemented at least 3 years previously. The study found that more than one-third of households with latrines had no member using the toilet, with 39% of members never having defecated in the household latrine. This

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[1] In 2011, the Government of India approved the name change of the State of Orissa to Odisha. This document reflects this change. However, when reference is made to policies that predate the name change, the formal name Orissa is retained.

observation about households that had a toilet, combined with the 28% of households that did not have latrines, suggested that most defecation events in these communities were being practiced in the open.

Aligned with how the Swachh Bharat Mission is increasing toilet coverage at a rapid pace, the study shows that mean latrine coverage among the villages was 72%, a major improvement over the less than 10% in comparable villages in the same district where the TSC had not yet been implemented. This highlights the fact that even though subsidies help in latrine coverage, widespread continuation of open defecation persists in the absence of targeted behavior change approaches.

Conventional wisdom has held that subsidies coupled with a few targeted awareness programs would be the solution to India's sanitation problems. IEC campaigns, in general, attempt to create awareness around a specific problem and thereby effect behavior change in a target audience. CLTS, as described above, is a more evolved and participatory form of IEC. A study was conducted on whether a hygiene intervention had a sustained impact and which particular activities appear more effective at stimulating behavior change (Shordt 2004). The intervention was carried out in a medium-term campaign, during which demand was created for latrines, payments were collected from households and local government, construction took place, and hygiene promoted. The IEC activities involved classes on hygiene education and mass activities such as video showings, street drama, exhibitions, and competitions for school children. Among other behaviors, use and maintenance of latrines was studied. The study found that consistent latrine use was reported by 78.1% of the men and women who voted. The difference between the practices of men and women in latrine use when at home was also found to be significant, with latrine use at 93.9% for women and 58.9% for men. This difference presents an interesting case. Pattanayak et al. (2009) noted that while more than 90% of households were able to cite open defecation as a cause of diarrhea, the awareness did not translate into improved use of toilets. On the other hand, attitudes and perspectives toward privacy and dignity played a greater role in influencing the demand for latrines from these households. IEC programs, when delivered within the right context, can thus prove to be effective in sustaining behavior change.

Besides these interventions, multi-pronged approaches have been identified to tackle non-use of latrines in rural India. As noted by O'Reilly and Louis (2014), "The elements of successful sanitation adoption depended on three factors i.e. toilet tripod: (1) multi-scalar political will on the part of both government and NGOs over the long term; (2) proximate social pressure, i.e., person-to-person contact between rural inhabitants and toilets; (3) political ecology, i.e., assured access to water, compatible soil type, and changing land use." A study also examined the sources of psychosocial stress related to the use of toilet facilities or open defecation by women and adolescent girls at home, in public places, at workplaces, and in schools in a rural community in Pune, India (Hirve et al. 2015). The study finds that fear for personal safety, injury or accidents, lack of cleanliness, indignity, shame, and embarrassment due to lack of privacy were significant sources of stress related to open defecation.

The evidence on latrine use and behavior change thus points to a complexity in the problem of open defecation that goes far beyond toilet construction and coverage that appears to be the focus of all sanitation policy programming in India so far. In the next section, we look at the evolution of sanitation policies in India and South Asia.

13.4 Overview of Sanitation Policies in South Asia

Much like the sanitation problem in India, the neighboring South Asian countries have struggled with the open defecation problem owing to similar cultural contexts.

Bangladesh, although a success story in terms of providing water to its people, with an estimated 98% access to improved water sources, faced sanitation challenges similar to those of India. As of 2010, access to adequate sanitation facilities was pegged at 56% of the population. CLTS contributed significantly to the improvement of access to sanitation facilities since 2000. The World Health Organization (WHO)–UNICEF Joint Monitoring Programme estimated access to improved sanitation in Bangladesh to be 61% in 2015 (WHO–UNICEF 2015). To address the sanitation challenge, the government targeted its policy efforts toward decentralization of service provision, user participation, particularly with regard to women, and looking into sanitation marketing with pricing rules.

Participative models continued to be popular after 2000, with a national sanitation policy (NSP) in Pakistan promoting CLTS in 2006. Through the NSP, the government also provided monetary incentives in the form of rewards for ODF urban clusters—tehsils, towns, and industrial estates (Government of Pakistan 2006). The NSP was followed in Pakistan by the National Drinking Water Policy of 2009 but no concentrated efforts were made toward sanitation.

Nepal has made concentrated policy efforts toward sanitation since 1994 when its first NSP was produced under the Ministry of Housing and Physical Planning. While this was more in the form of directives and objectives, the government launched the Rural Water Supply and

Sanitation National Policy, Strategies and Sectoral Strategic Action Plan in 2004—an integrated policy for sanitation and water. However, this policy focused more on rural water supply and did not consider sanitation in the same detail as the 1994 NSP. The National Guidelines for Hygiene and Sanitation Promotion were formulated in 2005 within the integrated policy framework. The overall policy and guideline objectives were framed with an intention to improve coverage to be achieved and the institutional arrangements for implementing policy.

Policies remain focused on improving toilet coverage and service provision through decentralized implementation. No concentrated efforts toward ensuring health outcomes and behavior change have been made.

13.5 Evolution of Sanitation Policy in India

Table 13.1 gives an overview of the key milestones in rural sanitation in India since independence in 1947.

As the table shows, India's attempts to tackle the problems of rural sanitation take concrete shape with the Central Rural Sanitation Programme (CRSP), which was started in 1986 to provide sanitation facilities in rural areas. The CRSP had a massive outlay of $138 million. While 9.45 million latrines were constructed for rural households, only a marginal increase of an annual 1% was achieved, with very little community participation.

As documented by the National Rural Employment Guarantee Act website, "It was a supply driven, high subsidy and infrastructure oriented programme. As a result of these deficiencies and low financial allocations, the CRSP had little impact on the gargantuan problem."[2]

While it is recognized in government documentation that the CRSP has little impact, since most of these were attributed to implementation failures, the policy programming continued with the subsidies. The reduction of the household toilet subsidy was one of the major policy changes in the TSC compared to the erstwhile CRSP. The TSC allotted a maximum subsidy of ₹600 per household, sharply in contrast to the ₹2,000 per household under the CRSP. It is to be noted that the subsidy of ₹600 was only for the Below Poverty Line (BPL) families and was not supposed to cover the entire cost of construction of the toilet, but to be treated as an incentive for adopting a toilet and the corresponding good hygiene behavior. The reduction in the subsidy was guided by the

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[2] Retrieved from the National Rural Employment Guarantee Act website from a publication on the TSC. http://www.nrega.nic.in/netnrega/forum/8-TSC.pdf.

Table 13.1: Key Milestones in Rural Sanitation in India

Year	Milestones in Rural Sanitation in India
1949	Dug well-type latrine developed at Singur
1954	The rural sanitation program introduced as part of the first Five-Year Plan of the Government of India
1953–56	The twin pit pour flush latrine evolved and was field-tested at Singur, West Bengal by AIIH&PH, Calcutta
1972	The Accelerated Rural Water Supply Programme started by the government to provide drinking water supply to problem villages
1980	Development of rural plan, consuming less water
1981	Census reveals the rural sanitation coverage to be a meagre 1%
1981	International decade for drinking water and sanitation begins emphasis on rural sanitation
1984	Guinea worm eradication program launched
1986	National Drinking Water Mission set up by the government and the Central Rural Sanitation Programme (CRSP) launched
1992	National conference on rural sanitation organized by the government
1992	CRSP restructured
1996–97	National level Knowledge Attitude and Practice (KAP) study conducted
1998	National conference on rural sanitation organized by Rajiv Gandhi National Drinking Water Mission
1999	CRSP restructured and Total Sanitation Campaign (TSC) launched
2000	WHO-certified eradication of guinea worm from India
2001	Rural sanitation coverage increased to 21.9%
2002	Allocation-based CRSP phased out and TSC becomes the national sanitation program Guidelines for setting up communications and capacity development units (CCDU) in states initiated
2003	The first South Asian Conference on Sanitation organized in Dhaka
2004	CCDU guidelines approved by the government. Second revision in TSC guidelines carried out
2006	Third revision in TSC guidelines carried out in March and subsidy for household toilets increased The first international learning exchange in water and sanitation sector organized in November jointly by UNICEF and Government of India
2014	Swachh Bharat Mission launched[a]

[a] Not part of the table in the source document.

Source: Alok (2010).

Knowledge, Aptitude and Practice (KAP) study (Mitra 1998), which revealed that about 51% of households without toilets were willing to spend up to ₹1,000 for one. Alok (2010) reported that the KAP study clearly revealed that the subsidy was not the key motivational factor and people were willing to spend money to construct latrines.

Thus, in principle, the TSC tried to move away from the subsidy model and sought to be a community-led, people-centered, demand-driven, and incentive-based program (Peal, Evans, and van der Voorden 2010) to address India's rural sanitation crisis.

The policy failure of the TSC is well documented. The 2011 census data showed 31% sanitation coverage in 2011—an improvement upon the 22% observed in 2001. However, this was significantly lower than the 68% reported by the government under the TSC. The decade, in fact, witnessed progress slowing. An increase of 8.3 million households without latrines was reported. Hueso and Bell (2013), drawing on evidence from two coordinated studies in four Indian states, found that TSC implementation was unaligned with the program's guiding principles and attributed the theory-practice gap to low political priority, flawed monitoring, distorting accountability and career incentives, technocratic and paternalistic inertia, and corruption.

The TSC's poor performance was officially confirmed in late 2011 when India's Minister of Drinking Water and Sanitation stated that the TSC, "has been a failure. It is neither total, nor sanitation nor a campaign" (Tandon 2011). On 2 October 2014 the government relaunched the TSC as the Swachh Bharat Abhiyan (Clean India Mission) with great fanfare.

13.6 The Swachh Bharat Mission: Behavior Change and Sustained Use

The SBM was launched on 2 October 2014, with an aim to construct 90 million toilets in rural India to eradicate open defecation by 2 October 2019 (Business Standard 2016). The SBM is a nationwide program spanning 4,041 statutory cities and towns.

Under the SBM, an incentive of ₹15,000 is provided to a BPL family for each toilet constructed. At an overall estimated cost of over ₹620 billion ($9.5 billion), the SBM is India's biggest sanitation campaign to date. As of February 2018, the government reported sanitation coverage rising to 80% from 38.7% in October 2014. Eleven states, 314 districts, and 325,000 villages have been declared ODF as of February 2018.[3]

[3] Figures available and updated in real-time on the Swachh Bharat Mission website.

Much like its predecessor, the SBM attempts to be people-centered, community-led, demand-driven, and incentive-based. The mission guidelines (Ministry of Drinking Water and Sanitation 2017) are clear on incorporating behavior change and/or IEC in the program: "Behaviour change has been the key differentiator of Swachh Bharat Mission and therefore the emphasis is placed on Behaviour Change Communication."

The policy leans toward approaches like the CLTS mentioned earlier, "since Open Defecation Free villages cannot be achieved without all households and individuals conforming to the desired behaviour of toilet use every day and every time, community action and generation of social norms are key." The guidelines focus heavily on triggering communities and on achieving collecting behavior change. The focus is also on use of Interpersonal Communication, especially for triggering of demand and use of toilets through social and behavior change communication and house-to-house interventions.

As described in previous sections, the problem of latrine use is complex and requires multi-level interventions that target psychosocial aspects of usa. The SBM, however, does not demonstrate any novelty in thinking about behavior change and relies only on IEC and community-led approaches.

13.6.1 ODF Declaration and Verification

The Guidelines for ODF Verification[4] define ODF as follows:
ODF is the termination of faecal-oral transmission, defined by a) no visible faeces found in the environment/village; and b) every household as well as public/community institutions using safe technology option[5] for disposal of faeces.

The checklists for a *gram panchayat*/Village to be declared ODF are in the appendix. As sanitation is a state subject, the ODF verification mechanisms are left to the states. A closer look at the guidelines presents loopholes in the approach. Some loopholes worth noting are presented below:

- There is a cause of concern because the definition of ODF does not take into consideration the use of toilets. The definition only looks at visibility and disposal of faeces. If the behavior change is targeted toward toilet use, then it must be incorporated into the definition.

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[4] Retrieved from the website of the Ministry of Drinking Water and Sanitation. http://www.mdws.gov.in/sites/default/files/R_274_1441280478318.pdf.

[5] Safe technology means no contamination of surface soil, ground water, or surface water; excreta inaccessible to flies or animals; no handling of fresh excreta; and freedom from odor and unsightly condition.

- Even though there are two verifications proposed to ensure sustainability, a footnote in the guideline mentions that a verified village, district, or state does not necessarily lose its ODF status on account of "slip-back" by some households or outsiders. This demonstrates a lack of institutional understanding of the complexity of behavior change. Emerging knowledge posits sanitation and hygiene behavior change as, "a non-linear process where it seems that becoming ODF is just the first step in a community learning process to reach behaviour change maturity" (WSSCC 2018).
- In the case of the TSC, it happened that the reported figures by the government may have been falsified. It was thus imperative that the verification was carried out only by a third-party evaluator to provide more credibility.
- While there is one question to ascertain 100% use, it is discussed in the next sections that measuring latrine use is also a much more complex issue than it seems.

Overall, the program guidelines demonstrate apathy toward the complexity of behavior change, toilet use, and the issue of slippage, which is dynamic, highly varied, and context-specific.

13.6.2 Practitioners' Perspectives and Implementation Challenges of the SBM

Senior government officials and grassroots workers in the states of Bihar and Jharkhand implementing the SBM were interviewed in April 2016 in connection with multilateral efforts to effect behavior change through CLTS. The following implementation challenges emerged across both Bihar and Jharkhand that have implications on behavior change and toilet use:

- Mismatch between demand and supply was a major reason why the program was not gaining traction. The SBM is highly inclined toward community-led approaches. Cases were reported where a village community was triggered, but equipment was not available. Since CLTS is about spontaneous disgust and shame, when the supply was not available, people had no choice but to give up on the hope of constructing their toilets. Re-triggering was not received well. Sanitary marts that provide resources in time at affordable prices may go a long way toward translating triggered demand into toilet use.
- There was an acute shortage of personnel able to interact regularly with the community. Sometimes, even four or five

villages are clustered together for one CLTS demonstration. This results in poor delivery of the program.

- It was also reported that there is no real focus on post-ODF monitoring because there is not enough personnel to engage with the communities and there are no clear guidelines on what encompasses the monitoring process.
- The IEC messaging on good hygiene practices may be effective in certain cases, but it is very important that the users, especially in rural areas, are made aware of the know-hows of the operation and maintenance of the toilets that are constructed. This is crucial to sustained use as most people with pit latrines think that the pits will fill up. This problem is further aggravated by the fact that masons in rural areas who are trained in construction of toilets migrate seasonally, making it difficult to carry out minor repairs.
- The timing of the incentive payment is a matter of contention. While upfront payment for toilet construction is a major obstacle for the poorest of the poor communities, there is a risk with pre-construction disbursement of incentives that it would be used for other purposes.

13.7 Discussion

Considering the gaps in the policy programming, three key aspects emerge for discussion to inform about sanitation policies for them to be more effective and achieve intended outcomes:

1. Latrine use measurement for ODF verification
2. Slippages
3. Behavior change

13.7.1 Measuring Latrine Use for ODF Verification

The measurement of latrine use is a complex process and requires triangulation methods and data to arrive at accurate figures. Lahiri et al. (2017) observed that no measurement method perfectly captures actual latrine use, and all indices in this domain are prone to errors of sensitivity and accuracy. While academics have used sensor devices like passive latrine use monitors (PLUMs) to measure latrine use in studies, it is to be noted that the scope of the discussion in this chapter is to check whether the self-reporting for the question on 100% use in the ODF-verification questionnaire provides a reliable estimate. If not, potential ways in which the ODF status is bestowed remains a question.

In that regard, comparisons of other techniques with self-reporting adds value to the discussion. As Lahiri et al. (2017) pointed out, the danger of Hawthorne effects or social desirability is inherent when information on use is solicited from individuals using self-reporting questionnaires. This is evidenced by the work of Sinha et al. (2016), where self-reported daily latrine use is 118% higher, on average, than PLUM-recorded latrine use. There is also a potential for recall bias evidenced from the fact the discrepancy in reported numbers was considerably reduced when PLUM-recorded incidences were compared at the 48-hour recall.

In the policy context, while self-reporting may be the most convenient and cost-effective way to measure latrine use, if the aim is to achieve a community free of open defecation, it would be better to understand individual use patterns instead of asking for aggregated household latrine use. This might help in understanding use from perspectives such as gender and vulnerable groups. Since the declaration of ODF also involves rewards for the community, there is bound to be a tendency to provide socially desirable answers in order to achieve the reward.

Policy programming needs to keep these considerations in mind.

13.7.2 Slippages

The term "slippage" refers to a return to unhygienic behavior, or the inability of community members to continue to meet all ODF criteria. The issue of slippage related to behavior change is very context specific. The Water Supply & Sanitation Collaborative Council's Global Sanitation Fund[6] has identified various slippage patterns:

- Slippage due to noncompliance with ODF criteria

This kind of slippage could occur in policy contexts that have stringent criteria imposed and any deviation from the said criteria would deem the entire community and/or geography non-ODF.

- Community-wide slippage

Poor CLTS implementation and follow-up could lead to a community-wide slippage where a large majority in the community go back to defecating in the open after the community has achieved ODF status.

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6 For information on the Global Sanitation Fund: https://www.wsscc.org/global-sanitation-fund.

- Seasonal slippage

Seasons can affect ODF status as people in water-scarce regions in dry seasons may resort to defecating near sources of water. Wet seasons may also make it difficult for people to access distant toilets with uncovered paths or in unhygienic locations.

- Slippage of convenience

When slippage occurs in common areas outside the community frequented by people, it is mostly on grounds of poor understanding as to why community members must stop defecating in the open.

- Externally induced slippage

In rural areas around festive seasons when rural communities entertain visitors, facilities can be over-stretched and an externally induced slippage is recorded.

- Institutional slippage

Conflicting policies or lack of coordination on the part of institutions implementing sanitation activities may lead to institutional slippage.

Since government officials implementing the SBM raised a concern about monitoring, there is scope to include the measurement of slippage as an important management tool for programming and monitoring.

13.7.3 Rethinking Behavior Change

In a world of nudges and evolving behavioral sciences, it is obsolete for behavior change to be focused only on IEC and change communication. Traditional demand-driven approaches (such as the CLTS) have focused on conscious, reflective systems in which individuals deliberate and think through alternative choices before making a decision (Neal et al. 2016).

Emerging evidence and integrative frameworks for understanding and changing behavior (Michie, van Stralen, and West 2011) look at human behavior as an interacting system in which capability, motivation and opportunity interact. Thus, a combination of three factors, i.e., the performance abilities, motivation (although not necessarily conscious), and environmental opportunities, form the necessary and sufficient conditions for behavior change.

It is not new for policy to learn from academics. The TSC, although an implementation failure, was informed by the national level KAP study. Hence, frameworks such as the Risks, Attitudes, Norms, Abilities and Self-Regulation model may hold relevance. The model includes perceptions, attitudes, beliefs, abilities and self-regulation as the main drivers of behavior change and habit formation (Mosler 2012).

Basing behavior change on theoretical understanding may help in achieving more sustained outcomes. There might be great potential in trying out behavior change interventions that look at automatic psychological processes, as in the MINDSPACE[7] framework (Dolan et al. 2010).

13.8 Conclusion

This chapter highlights the gaps in the institutional understanding of behavior change and loopholes in the ODF verification guidelines. With regard to the ongoing SBM, the following emerge as key points:

- The concept of behavior change in the guidelines focuses on IEC and community-led approaches with a target to generate demand for toilet construction. The complexity of the problem of toilet use and psychosocial aspects seem to be ignored. No novelty is observed in the policy's approach to sustaining behavior change.
- The ODF verification mechanism seems more targeted toward convenience in reporting for the figures for the government than achieving actual positive health outcomes. The issue of slippage is being completely ignored by policy, jeopardize sustainability.
- From an implementation perspective, there seems to be a mismatch in demand and supply of resources, leading to poor uptake. However, coverage has reportedly reached about 80% as of February 2018.

Overall, more political will, novelty in approach and rigor in understanding are required to effect behavior change that will lead to improved and sustained latrine use in rural India.

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[7] This mnemonic framework reflects an attempt to establish the most robust effects on behavior that operate largely through automatic psychological processes. Automatic motivations are broken down into more basic motivations that drive human behavior: Messenger; Incentives; Norms; Defaults; Salience; Priming; Affect; Commitments; Ego.

13.9 Recommendations

- Devise multi-level interventions based on integrative behavior change frameworks to effect sustained behavior change. These interventions could come in the form of how IEC material is framed and communicated, making toilets more appealing by improving or adding functionalities, and targeting social and cultural norms.
- Focus on health outcomes and the use of toilet outcome in the ODF verification process. Local dispensaries and hospitals must report positive health outcomes in order for the community to be declared ODF.
- The verification of toilet access and use must be carried out by an independent evaluator to ensure objectivity in reporting.
- Build capacities at the grassroots and local nongovernment organizations to monitor and address the various types of slippages.

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Appendix 13: ODF Verification Checklist for a *Gram Panchayat*/Village to be Declared ODF

The answers to the household survey questions 1, 2, 3, and 4 should be necessarily Yes for a village to be ODF. In addition, the answers to the questions 8, 9, 10, 11, and 12 should also be necessarily Yes for a village to be ODF.

a) Household survey

Parameters	Yes (✓) or No (X)
1) Access to toilet facility	
2) 100% usage	
3) Fly-proofing of toilet	
4) Safe septage disposal	
5) Hand-washing before meals	
6) Hand-washing with soap after defecation	
7) Availability of soap and water in or near the toilet	

b) Village survey

Parameters	Yes (✓) or No (X)
8) No visible faeces found in the environment/village	
9) Proper usage of school toilet	
10) Safe confinement of excreta in social toilet	
11) Proper usage of Anganwadi toilet	
12) Safe confinement of excreta in Anganwadi toilet	

14

Assessing the Double Injustice of Climate Change and Urbanization on Water Security in Peri-urban Areas: Creating Citizen-Centric Scenarios

Arvind Lakshmisha, Priyanka Agarwal, and Manasi Nikam

14.1 Introduction

Urban areas provide several ecosystem services, of which water is an essential service. However, water resources are especially affected in developing countries because of the lack of efficient planning and poor implementation of programs regarding water services and infrastructure, which is further exacerbated by the increasing population. The institutional and governance challenges hindering effective adaptation are insufficiently explored compared to technical and engineering solutions. Research has indicated that users of urban commons such as lakes, ponds, and community gardens do not have formal ownership over the lands they access, but have access to other property rights (withdrawal, management, and exclusion) in contrast with rural areas where water bodies, especially surface water, are managed as common pool resources (Ostrom 2007).

In India, the National Water Policy 2012 (NWP 2012) and the Karnataka Water Policy (KWP 2002) function on the premise that water is a scarce resource, and that there are increasing amounts of pressure in the form of demands from various sectors. The NWP 2012 points to the risk of conflicts between water using groups in the face of scarcity. It is also concerned with the inequitable distribution of water, which goes against the principles of social justice. The NWP 2012 reemphasizes the public trust doctrine in the use of water. Similar to the

United Nations Agenda 2030 for Sustainable Development, which calls for collaborative partnerships, suggesting framing policies based on stakeholder participation leading to inclusive policy making, the KWP 2002 identifies "Participatory Management" as one of the thematic areas as a necessity for water resource projects.

This study assessed how urbanization in conjunction with climate change has impacted this interface on the periphery of urban areas underscoring the need for inclusive and participatory planning to achieve national and international goals including the relevant Sustainable Development Goals (SDGs). In line with the targets of SDG 11, the study aimed to provide a platform for communities and policy actors to interact and thus undertake a participatory approach in urban planning. The study also highlighted the need to support and strengthen local community capacities to improve water and sanitation management as mentioned in SDG 6 to ensure that resource scarcity does not lead to resource insecurity.

14.1.1 Scope

This study documents the experiences and perceptions of peri-urban communities on water security, through a case in the peri-urban areas around Bangalore, India. The study is set in the Manchanaykanahalli *Panchayat*[1] (MP) in the periphery of the metropolitan city of Bengaluru in Southern India. MP was selected due to its proximity (50 kilometers) to the city, in addition to the location of Bidadi Industrial Estate, one of the prominent industrial estates around Bangalore, known for its manufacturing industries. Further, MP is located along the Bangalore–Mysore Expressway, which runs parallel to the Vrishabhavathi River. The river carries nearly 50% of Bangalore's wastewater and is the main source of water for agriculture, a highly practiced occupation in and around the *panchayat*. The study captures the perceptions of communities in seven villages in this *panchayat* on how urbanization and change in rainfall patterns have affected water security in their villages. Seven villages were studied: Manchanayakanahalli, Shanamangala, Hejjala, Talakuppe, Billakempanahalli, Lakshmisagara, and Inorapalya.

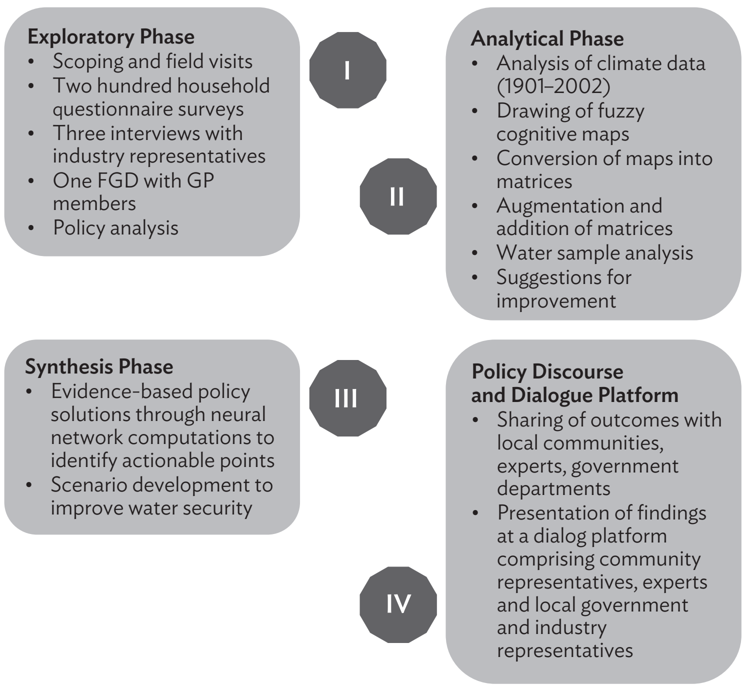
14.1.2 Study Approach

The study used a mixed methods approach to gather and analyze data through household surveys, focus group discussions, water sample analysis, and interviews. It also uses the cognitive mapping approach

1 *Panchayat* is one of the administrative levels in India.

to gather perceptions on water insecurity by the local communities. This is done using the climate change scorecards, developed by the Public Affairs Centre, as a tool to move research away from top–down, extractive information gathering toward participatory, bottom–up, and inclusive knowledge generation (the steps are described in Figure 14.1). The study uses cognitive mapping to capture the understanding of insecurity and identify pathways for evidence-based policy simulations for reducing water insecurities in peri-urban areas. Fuzzy cognitive maps (FCM) were developed to simulate alternative policy options based on the local needs coupled with the current policy environment. FCMs are a graphical representation of an actor's knowledge or perceptions associated with a given system (FCMappers 2018). FCMs are typically

Figure 14.1: Four Phases of the Study



FGD = focus group discussion, GP = *gram panchayat* (village council).

Note: A GP is an institution of self-government for the rural areas, constituted under article 243B of the Indian Constitution. It is a formalized system in India for self-government at the village or small town level.

Source: Authors.

weighted graphs with feedback and directed links connecting nodes, which describe the behavior concepts of the system (Papageorgiou 2011). Papageorgiou (2011), based on Codara (1988), highlights the main purposes where FCMs can be of potential help:

- to aid in the generation of accurate descriptions of a complex and dynamic situation;
- to help decision makers better understand a given situation and ascertain the adequacy and bring in possible changes; and
- to simulate future action strategies and decisions based on the reasoning given by local actors to justify occurrences.

FCMs are developed by integrating the knowledge and existing experience of a system through the use of actors and stakeholders to describe the behavior and structure of a given system. The maps are seen as a simple and quick method to gather knowledge from various distinct sources and levels at the lowest cost and are also easily understandable to non-experts (Obiedat and Samarasinghe 2016; Papageorgiou 2011). Further, FCMs within a specific domain can be combined mathematically, allowing for incorporation of views and knowledge of diverse stakeholders, both experts and non-experts (Kosko 1993, 1986). FCMs are a useful approach to capture and reflect the reality of complex social ecological problems. Though they are used highly in the fields of business and engineering, there is a growing interest to apply the method in the social and natural sciences. There are several research applications of FCMs in various fields such as in agriculture (Papageorgiou, Markinos, and Gemtos 2010; Papageorgiou, Markinos, and Gemtos 2009; Kafetzis, McRoberts, and Mouratiadou 2010), ecological problems (Ozesmi and Ozesmi, 2004), agro-forestry management, sustainable agro-ecosystems, water use and water use policy (Kafetzis, McRoberts, and Mouratiadou 2010), and so on.

14.2 Vulnerability and Adaptation to Peri-urban Water Security: Conceptual Premise

14.2.1 Peri-urban: A Space Caught in Between

We are witnessing an era of rapid urbanization with extraordinary growth of cities proceeding at an unprecedented scale. The extreme changes of urbanization are expected to take place in the "Global South" (Montgomery 2008; Seto et al. 2011), mainly in the form of rural-to-urban transformation (Nagendra and Ostrom 2014, 2012). These transformations are concomitant with widespread changes in land use and increasing consumption. In the process of urbanization, commons such as lakes, ponds, parks, and gardens are the initial casualty, as they often have multiple, contested uses and therefore are subject to conversion and degradation (Nagendra and Ostrom 2014). More often than not, the commons are situated in the urban fringes, termed the peri-urban interface (Mundoli, Manjunath, and Nagendra 2015). For an urban user, they represent recreational value, whereas for traditional users and the urban poor, they provide livelihood services. This difference in value systems are shaped by the community of users and create winners and losers, which are due to the large-scale structural transitions over which users have very little control (Simon 2008).

Allen (2003) defines the peri-urban interface as a “complex mosaic of rural, urban and natural subsystems” (Mundoli, Manjunath, and Nagendra 2015) “with distinct environmental, social and institutional characteristics, which form due to urban–rural interactions” (Narain and Nischal 2007). Peri-urban is considered an elusive phenomenon, which can be partially attributed to the conceptual difficulties associated with it. The theories around peri-urban areas classify them into three categories: peri-urban as a place, as a concept, and as a process. As a place, peri-urban areas are often looked at as sites of expulsion from the city that makes way for visions of modernity. As a concept, Narain and Nischal (2007) define peri-urban areas as interfaces between rural and urban activities and institutions (as cited in Mehta and Karpouzoglou 2015). As a process, peri-urban areas are seen as transition zones, where there is an inevitable decline of rural activities, which require little attention. They are thus bypassed by authorities, leading to ambiguities in the administrative and jurisdictional structure of the area and further to systematic exclusions of poor and marginalized citizens (Mehta and Karpouzoglou 2015).

Peri-urban areas comprise a unique, transitional space in terms of social and ecological characteristics that are both urban and rural in nature. Consequently, these areas are characterized by serious challenges of governance (Simon 2008). Traditional planning models fail to incorporate specific issues of interactions between urban and rural institutions, aggravated by information asymmetries and the lack of a common jurisdictional unit (Mundoli, Manjunath, and Nagendra 2015). There are periods of regulatory slippage in the periphery of cities during rapid growth, which accompanied by inadequate infrastructure “hamstrings” the government in regulating the use of commons (Foster 2013). Aguilar (2008) posits that the severe ecological and environmental challenges in the fringes of the cities are aggravated by the lack of implementation of plans and ineffective governance. However, since the trajectory of degradation is recent and easy to undo and land prices are reasonable, it is possible to implement cost-effective conservation measures (Theobal 2004).

Peri-urban areas rely more on natural resources as compared to cities (Mundoli, Manjunath, and Nagendra 2015). Research in the peri-urban areas highlights that these areas constitute centers of intense social heterogeneity, causing existing social networks to fragment (Nicholls 2008). These areas are marked by a confusing mix of urban and rural institutions, policies, and laws, and where the focus of control over commons shifts to a different level (communities to city municipality), This is coupled with the scarce opportunities for dialogue and coordination between various levels of government (Narain and Nischal 2007).

14.2.2 Urbanization and Climate Change: Stressors of Peri-Urban Water Security

The United Nations (UN) defines water security *"as the capacity of a population to safeguard sustainable access to adequate quantities of acceptable quality water for sustaining livelihoods, human well-being and socio-economic development, for ensuring protection against water-borne pollution and water-related disasters, and for preserving eco-systems in a climate of peace and political stability"* (UN-Water 2013). Although access to potable water is considered a basic human right, the UN reports that nearly 1.8 billion people utilize water that has fecal contamination and nearly 40% of the world's population does not have safe access to water (UN 2015). In India alone, nearly 76 million people lack access to clean water, and a higher proportion of the population faces water scarcity and satisfies itself with irregular access to water (Water Aid 2016). Residents of peri-urban areas are in the latter group; they negotiate water security, driven by factors unique to the peri-urban space. Narain (2011) in his analysis of water issues in peri-urban areas highlights three domains over which conflicts take place: quantity of water, quality of water, and access to water resources. These three categories also emerge in the investigation by Allen, Davila, and Hofmann (2006) of a group of people termed the "peri-urban water poor." This group is categorized through its informal, poor quality, and insufficient access to water, and adopts the above three dimensions of water security (quality, access, and quantity), discussed respectively in the following paragraphs, to understand the impact of urbanization and climate change on the same.

Peri-urban populations dependent on rivers flowing downstream through the urban core receive heavily contaminated water due to the improper disposal of residential and industrial wastes (Simon 2008).

Further, given the availability of free open spaces, peri-urban areas become the dumping ground for urban waste (Prakash 2014). This unregulated waste disposal leads to sanitation issues and contaminates the land and water resources, affecting the health and livelihoods of peri-urban residents. Such a state is largely attributable to the lack of industrial regulations in peri-urban areas aggravated by the lack of sanitation and waste management infrastructure in peri-urban areas (Simon 2008; Janakarajan et al. 2007).

The frequency of water supply in peri-urban areas is often low. In their analysis of Hyderabad's peri-urban areas, Arha, Audicha, and Pant (2014) highlight discrepancies between Hyderabad's low-income peri-urban households who are supplied water on alternate days for a few hours and the quantity of water supplied to industries and other corporate bodies in the area. Depending on the extent of contamination of water and frequency of water supply, peri-urban households may resort to buying water from other sources such as mineral water companies. However, market-based solutions may not always be affordable to peri-urban residents. At times, peri-urban dwellers also lose all access to their traditional sources of water. In their analysis of the peri-urban interface in Shahpur Khurd, Narain and Nischal (2007) note that three ponds in the village traditionally used by residents are now auctioned off by the village *panchayat* to fisheries contractors.

Urbanization of previously rural spaces inherently increases demand for water due to larger population and additional industrial consumption (Lakshmi and Janakarajan 2005). The quantity of water available in peri-urban areas is also jeopardized, as more and more is drawn from these areas to meet the increasing demand for water in cities that have depleted their original sources of water (Noman and Sohail 2003). For instance, the metropolitan water board transports more than 6,000 tanker loads of water each day to Chennai city from its peri-urban areas (Janakarajan et al. 2007). Mineral water companies also extract groundwater from peri-urban areas to purify and sell it (Janakarajan et al. 2007). There are presently 200 bottling companies operating in areas around Chennai that do not pay license fees, resulting in the unregulated exploitation of groundwater. The unregulated extraction and exploitation of groundwater has affected many cities. The District Irrigation Plan 2015 of Bengaluru Urban District shows that the stage of groundwater extraction in Bengaluru ranges from 128% to 176%, varying by subdistrict.[2] Similarly, the stage of groundwater development

[2] Subdistricts are administrative units below a district marked off for administrative and taxation purpose. They are also referred to as *tehsil, taluk*, or *taluka* in various parts of India.

in the city of Hyderabad is 864%. Most states in India have laws that regulate construction of bore wells, but enforcing agencies have poor capacity (Araral and Yu 2013). Indeed, the ceaseless exploitation of peri-urban water resources has an impact on the regenerative capacity of groundwater systems. For example, in his analysis of peri-urban water security in Gurgaon, Narain (2011) comments on the lowering of the water table in the region over the past decade—in some cases up to 300% lower than the initial levels.

A similar pattern of water insecurity caused due to unplanned urbanization is observed in other peri-urban areas in Asia. Sajor and Ongsakul (2007) in their study on water governance in Bangkok describe the deterioration in the water quality of canals due to the discharge of untreated industrial effluent and domestic wastewater. The use of this water for irrigation purposes has adversely affected the livelihoods of low-income farmers. In another study of 12 major peri-urban areas in Bangladesh, farmers reported using untreated domestic wastewater for agricultural purposes and the resultant skin infections. They also reported injuries and damage to pumps caused by solid wastes (Mojid et al. 2010). In Khulna city of Bangladesh, there are conflicts between urban and peri-urban users as fresh water sources are being polluted due to unplanned urbanization in addition to importation of water into the urban areas from peri-urban localities (Kumar et al. 2011). Narain et al. (2013) in their paper on water insecurity in peri-urban areas of South Asian cities state that in Kathmandu in Nepal, water security of peri-urban residents is compromised by the excess physical flow of water through commercial water tankers from peri-urban to urban areas. They noted that increasing pollution in the Hanumante River prevented farmers from using the river water for agriculture.

In addition to such urban drivers of water shortage, climate variability has also been reported to lead to a reduction in the quantity of available water. For instance, in their study of the Orangi Township in Karachi, Ahmed and Sohail (2003) mention how poor rainfall over a continuous 10-year period led to a severe water shortage in the region, which previously had ample supply of water. Projections made by Kumar et al. (2011) in their study of peri-urban areas in Khulna in Bangladesh state that climate change will induce an increase in sea levels and intrusion of salinity in ground and surface water. Shrestha, Sada, and Melsen (2014) in their paper on urban and climate change in peri-urban areas of Kathmandu showed an increasing trend in temperature in the region. They captured people's perception on rainfall, which they opined to be erratic and thus not dependable for agricultural needs. An analysis of climate data for the city of Gurgaon in India indicates an increasing trend of the annual minimum temperature, but shows no change in the trend of annual maximum temperature. Whereas the total annual rainfall has shown a decreasing trend in the last 50 years, it is highly erratic (Khan et al. 2013). Such climate-related drawbacks further exacerbate the water shortage in peri-urban areas.

14.2.3 Adaptation to Water Security: Collaborative Partnership

Given the dual failure of both the state and the market, several scholars have resorted to calling for greater community involvement in addressing issues of water security (Araral and Wang 2013). In analyzing the plight of a peri-urban community in Chennai, Shaw (2005) proposes "looking beyond dependence on government and attempting to solve problems through community or local involvement." Citizen participation allows households, as key stakeholders in the issue of water insecurity, to identify and prioritize the problems to be addressed, set the agenda for action, and assess the efficiency of the measures taken to address problems (Swedish Water House 2007). Integral to citizen empowerment is the presence of the will for self-organization among communities, which can be in the form of an individual or an organization (nongovernment organizations) that enable and facilitate communities in identifying and addressing problems of water security (Dahiya 2003).

Watershed management at a local scale is favorably viewed, as it is ecologically meaningful and the measure of health of the aquatic ecosystem can be used for measuring the health of the overall watershed (McGinnis 1999). Partnerships engage citizens in self-governance, leading them to take control of their lives and communities by forging a new identity among residents as citizens of a watershed with all the benefits and responsibilities for ensuring good governance (Schlager and Blomquist 2008). As local communities coordinate with the government, there is a reduction in transaction costs for governments as collective activities are designed based on locally suited plans (Nagendra and Ostrom 2014).

A literature review of public–private community collaborations and partnerships in Asia highlighted two cities where communities proactively participated in resolving the issue of water insecurity. In Dhaka, Dushtha Shasthya Kendra, a local nongovernment organization, mediated between slum-based communities and the governing body to establish a sustainable water supply. It obtained permission from the city corporation to build water points, and mobilized slum communities and a few external donors to fund the construction of the water points. Gradually, 88 water points were established in 70 slum areas, benefiting more than 200,000 people, of which 12 water points have been paid for and handed over to the user groups (Allen, Davila, and Hofmann 2006).

A similar effort was made by citizens in Orangi Township of Karachi where local communities have established an informal system of water supply in collaboration with the Pakistani Rangers, the Karachi Water and Sewerage Board (KWSB), and commercial water tankers. Although the township had piped water supply in the beginning, the drying up of the Hubb River, which was the main source of water, created a water shortage. Thus, the municipality and provincial administration decided to collaborate with community organizations and build community-managed public tanks at various nodal points from where water would be distributed to citizens. To curb political influence on the supply of water, the Pakistani Rangers, a paramilitary force, administered the process. They enlisted commercial water tankers that sourced water from KWSB-approved hydrants to supply it to these tanks. The tanks were constructed by churches, mosques, and Pakistani Rangers on open grounds or public spaces. The distribution of water from these tanks to households was managed by mosque committees, neighborhood committees, and elders in the area. Thus, it was the partnership between local communities and local authorities that led to a solution to people's water woes (Ahmed and Sohail 2003).

There are examples where communities have undertaken initiatives to conserve water bodies and manage the demand and supply of water. In Khulna, citizens have collectively taken lease of ponds and protected them. In Hyderabad and Gurgaon, water is taken from upper-caste people, or friends or relatives in villages (Khan et al. 2013). However, in most cases, it was observed that the citizens, in the spirit of solidarity, had developed systems to conserve and manage the demand and supply of water singlehandedly, and had not institutionalized the efforts in partnerships and collaborations.

14.2.4 Adaptation to Water Security: Institutional Measures

Central, state, and local bodies have also taken steps to mitigate the issue of water insecurity, as in the case of Khulna in Bangladesh, and Chennai in India. In the case of Khulna, unplanned urbanization and increase in rainfall has caused flooding. The encroachment of *khals* (local name for a natural channel) has blocked the flow of water, leading to floods. To cope with this issue, the state authorities built climate-resilient infrastructure (Khan et al. 2013). In 2003, when Chennai was on the cusp of a quasi-draught, rainwater harvesting was made mandatory and 90% compliance was achieved (Kurian 2017). In another effort to revive water bodies and to remove encroachment on tanks, the city of Chennai constituted the Water Bodies Protection and Eviction of Encroachment

Act (2007). A citizen can, under this act, seek a public interest litigation if there is encroachment on water bodies for a remedy from the court (Narain, Banerjee, and Anand 2014).

A more concrete, policy-oriented measure to generate funds for water conservation initiatives was made by the Government of India, when in 2014, India became the first country to mandate and quantify corporate social responsibility (CSR) expenditure. In Section 135 of the Companies Act of 2013, every company, private or public, which has a net worth of ₹5 billion or a turnover of ₹10 billion, has to spend 2% of its average net profit for the preceding 3 years on CSR activities. The act also covered environmental sustainability as one of the activities under CSR spending. A study of 217 companies in India, conducted by The Economic Times, futurescape, and Indian Institute of Management Udaipur in 2016, revealed that 79% of the manufacturing companies and 47% of services companies have implemented programs to reduce water consumption. Thus, the policy has been able to provide an impetus for water conservation efforts.

This study promotes partnerships and collaborations between peri-urban communities and local governing bodies to make way for sustainable urbanization and solutions to emerging water security problems. Communities can provide firsthand experiences and knowledge of a particular area, water body, and climate that will complement the efforts and plans of local governing bodies to bring about sustainable solutions to water security and urbanization. The study seeks to add value to peri-urban research through its innovative approach and use of an inclusive and participatory citizen science approach to capture local concerns and develop policies to address impacts of a global issue such as climate change. This will help guide the policies and interventions taken elsewhere by demonstrating innovative approaches to the planning and governance of the peri-urban landscape (Wandl and Magoni 2017).

14.3 Water Security: Household and Community Perspective

14.3.1 Water Security: Analysis of Household Survey

This section deals with the issue of water security from a bottom–up perspective. This is based on household questionnaire surveys as well as interviews with the local administration and industry representative. The overarching issue of the unsustainable rate of groundwater extraction was seen to connect all the stakeholders interviewed. It can be said outright that water security in the villages was highly likely a function of increasing demand due to urbanization coupled with increasing variation in rainfall patterns. Further, the increasing demand for water was aggravated by the poor management of water resources. Even though water was supplied by the local administration through underground pipes and water tankers (this covers nearly 95% of the sample surveyed), in addition to people using groundwater for their consumption, more than 50% resort to buying water from vendors. This was used primarily for drinking and cooking, as the respondents indicated that the water that was supplied was of substandard quality.

This led to the testing of the quality of water supplied by the local administration and the water that is bought from the purification plants that use groundwater. This was undertaken at the water testing lab of the Environment Management and Policy Research Institute (EMPRI)[3] located in Bangalore. The test results indicated that the water supplied was acidic in nature with higher pH than permissible values. One of the samples from the purification plants were found to contain metal residue, in addition to being muddy. This corroborated the reports of the state government declaring groundwater unsafe for consumption.[4] Groundwater in the region was also found to be contaminated with fluoride, which was deemed unsuitable for drinking without treatment. Further, it was also indicated in the interviews that the groundwater had decreased from 450 feet to around more than 1,000 feet in the last decade. This can be attributed to the fact that the main source of water for the region is groundwater, as surface water sources are all polluted and carry the wastewater from Bangalore. This, in addition to the lack of enforcement of formal regulations against excessive extraction of water, has exacerbated the water insecurity in the area. It is further supplemented by the lack of awareness among the communities on how to harvest rainwater, as indicated by the survey that only 44% of the respondents had heard about rainwater harvesting.

14.3.2 Water Security: A Community Perspective

Apart from conducting household surveys and interviews, FCMs were created to summarize the perception of communities on what factors and how water resources are influenced in their villages. Community members who were engaged in farming, agricultural labor, dairy farming and industrial laborers were split into groups of two to four

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[3] EMPRI is the nodal public agency for research on climate change and environment research in the state of Karnataka.

[4] Based on interviews with members of the local administration.

persons (separate groups for men and women) and asked to draw maps to capture their perceptions on what influenced water security and how this affected their well-being. A total of 240 FCMs were drawn by the community members, which were aggregated into a single cognitive interpretation diagram to capture the influence of urbanization, climate variation (difference in rainfall and increase in temperature), and both urbanization and climate variations. Qualitative aggregation of all the maps into a simplified system in the cognitive interpretation diagram shows the connections to reflect the weight and sign of the causal relationships, as in the previous cognitive maps. Further to this, variables CSR and rainwater harvesting were included in the final maps to assess if these adaptive measures would influence water security in the region. The scores were included based on the discussions and interview findings with the industries, local administration, and the government policies that are currently under implementation.[5]

The cognitive interpretation diagram, which is a simplified version of aggregation of all the 240 FCMs (based on equal weights to all maps), is shown in Figure 14.2. The size of the variable (bubble) signifies the influence of an individual variable on other variables. A positive causal relationship is highlighted in black and a negative relationship in red links. Urbanization has improved financial conditions of the communities, and increased access to infrastructure and facilities. It was observed that urbanization has increased pollution, bearing a higher negative effect on agricultural livelihoods as people now preferred to work as industrial laborers. Further, this has also led to increased land-use change due to conversion of agricultural and common land for commercial and industrial purposes. This has negatively influenced the drinking water, groundwater, and surface water sources, as well as the health of the local communities. Although urbanization has increased financial capabilities, the communities are spending much more on collecting drinking water and on health-related problems, which negates the income generated through urbanization. Further to this, increasing variation in rainfall patterns was seen to affect agricultural practices and the overall food security of the communities, as they have moved from a self-sufficient agrarian community to now being dependent on purchasing their requirements. This change has also led them to shift from agriculture to allied activities such as cattle rearing and dairy farming. The communities attributed this to both urbanization and

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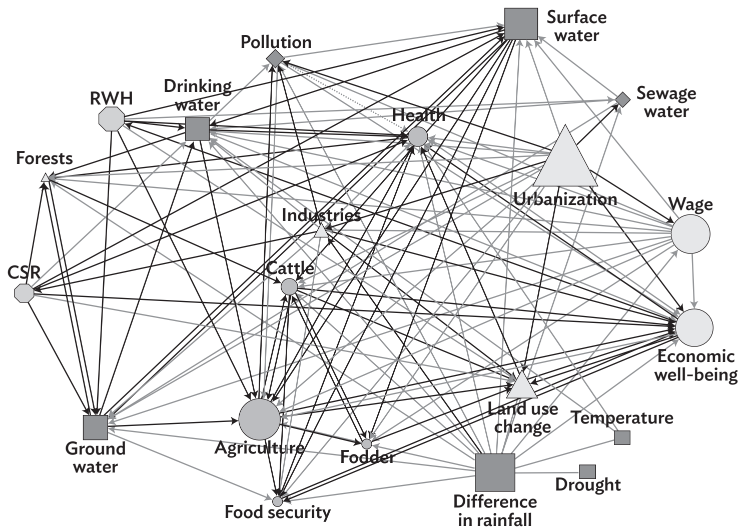
5 It is now mandated by Indian law that companies and industries must invest 2% of their profits for social causes. As the study area is located in Bidadi Industrial Estate, this plays a key role in improving water security in the area. This can also be seen in the interviews where the administration was looking forward to investments from industry bodies to set up purification plants (already in place in some villages).

Figure 14.2: Cognitive Interpretation Diagram Highlighting the Relationship between Climate Variation and Urbanization on Water Resources



CSR = corporate social responsibility, RWH = rainwater harvesting.
Source: Authors using FCMmapper and Pajek Software.

climate variation. Though this is largely practiced, the quality of milk produced was perceived to be substandard, due to the lack of fodder—and in many cases, use of fodder grown using contaminated surface water sources.

The condensed matrix was analyzed to identify the most influential elements of water security. This formed the basis for the scenario analysis and helped identify recommendations on how to improve the current conditions. Figure 14.2 highlights that the socioeconomic context of the communities are highly influenced by industries and pollution, including garbage and sewage disposal from urban areas. In addition, these variables also have a high influence on surface water sources including drinking water. Furthermore, the health of the local communities and agriculture is negatively affected by urbanization. This has led to an increase in land conversions and sale, resulting in improved economic conditions. Spillover from an ever-urbanizing Bangalore, while improving the economic conditions and infrastructure facilities such as schools, hospitals, and job opportunities in the study villages, has resulted in decreased water availability and accessibility. In addition, surface water was contaminated from urban sewage rendering the peri-urban communities vulnerable to water insecurity.

14.3.3 Developing Scenarios

FCMs aid to model different policy options and help identify and prioritize between options to improve water security. Two scenarios were developed based on the aggregated cognitive interpretation diagram. The scenarios were based on certain assumptions, which are detailed in the following paragraphs. Further, two variables were introduced for developing scenarios: increased spending through CSR and increased rainwater harvesting. They were chosen based on interviews with the local administration and the current policy atmosphere.

A number of initiatives by the industries have had an effect on the livelihood and quality of life of communities by intervening in the water sector. Further, the CSR policy of the national government, which states that 2% of a company's net profit is to be spent on social activities, has increased spending on various social activities (such as conservation, tree planting, education) directly or indirectly affecting water resources of regions. Increased spending through CSR was introduced in the scenario given the fact that the industries located around the study area have been active in pursuing various social objectives in the area. The local administration has set up reverse osmosis plants supplying drinking water in the *panchayat*, with support from industries. It was also indicated in the interviews with the local administration (*gram panchayat* members) that they are working with the industries to channel funding to help local communities and provide potable water.

The second variable. increased rainwater harvesting, was introduced in the scenario mainly due to the increased policy focus and the gaps identified in terms of implementation of rainwater harvesting. The draft rainwater harvesting policy by the Karnataka government, complying with the national and state water policies, stresses that it is necessary to implement rainwater harvesting to ensure holistic management of water resources. The Bangalore Water Supply and Sewerage Amendment Act, 2009 by the Bangalore Water Supply and Sewerage Board (BWSSB) has mandated for every owner or occupier of a building with a site area of 2,400 square feet more, or every owner who proposes to construct a building with a site area of 1,200 square feet or more to provide rainwater harvesting structures (The Hindu 2015). The Ground Water Act of 2011 had already brought up the need for rainwater harvesting, but there were large compliance issues with the BWSSB enactment as noted by its former chairman (The Hindu 2016). Moreover, very little awareness was reported in the study area. However, increased compliance is seen among people applying for new water connections since this is denied without the adoption of such rainwater harvesting systems.

The following two scenarios generated are worth highlighting.

Scenario 1: In this scenario, the following assumptions were made based on the current trend and the policy changes:

- increase in the change in land-use pattern (increased conversion of farmland to other uses),
- increased levels of pollution and sewage water, and
- increase in spending under CSR.

The first and the second assumptions are based on the Bangalore Metropolitan Region Development Authority Master Plan 2015, which indicates that Bangalore, will see increased development in the southwestern corridor and, based on the demarcation and expansion of the industrial estates, in the Vrishabhavathi watershed (Bidadi, Hrohalli, and Kanakapura) under the Greater Bengaluru Project.

In this scenario, water security in the region is seen to be affected negatively, as all three variables representing water resources (drinking water, surface water, and groundwater) show a strong negative change. Thus, with the current trend in development, a minor increase in CSR spending is not seen to have a positive impact on the water resources of the region.

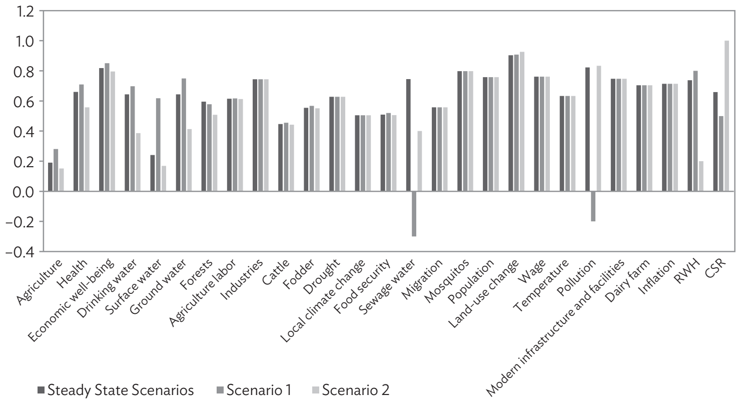
Scenario 2: In this scenario, the following assumptions are made based on the current trend and the policy changes:

- reduction in the levels of pollution and treating of wastewater before releasing it,
- increase in uptake of rainwater harvesting, and
- greater increase in spending under CSR.

The first assumption is based on the work that is being undertaken under the Atal Mission for Rejuvenation and Urban Transformation or AMRUT scheme, where the sewage treatment capacity of the city is planned to be increased from 721 million liters to 1,576 million liters (Deccan Chronicle 2017a), and also the inauguration of the new sewage treatment plant in March 2018 (Deccan Chronicle 2017b). These schemes undertaken upstream to the study area are assumed to have a positive effect on the water quality in the study area.

An increase in the spending of CSR in the region, in addition to minor reductions in pollution and increased treatment of wastewater, leads to improved conditions of water security, as is shown in Figure 14.3.

Figure 14.3: Observed Changes in Steady State under Scenarios 1 and 2



CSR = corporate social responsibility, RWH = rainwater harvesting.

Source: Simulated by the authors using FCMmapper.

Thus, planned spending of CSR with reduced levels of pollution due to enforcement of existing policies was found to enhance water security in the area. This sector will have positive repercussions on agricultural activities as well as the health of the people, cattle, and forests in the region.

Figure 14.2 shows that urbanization and the difference in rainfall have a strong negative impact on water security. Although urbanization and industrialization improved economic well-being and brought in modern infrastructure and facilities, this was offset (to a large extent) by the increased spending on health and purchase of drinking water. Difference in rainfall was seen to negatively affect the food security of communities, whereas changes in temperature affected agricultural practices, marginally reduced the availability of fodder, and impacted dairy farming. Urbanization led to drastic change in land-use patterns and increase of pollution levels as the Vrishabhavathi River that flows in the area has become an open sewer, carrying the wastewater generated in Bangalore. This water was used for agriculture in most areas; hence, respondents did not consider water insecurity for agriculture as a priority. The farmers have adapted to the use of wastewater for cultivation by changing the crops grown and now use low amounts of fertilizer and insecticide. The crops grown were sold in the urban market that is provided by the expanding city of Bangalore. Therefore, to improve water security in the area, there is a pressing need to decrease the levels of pollution and the ceaseless conversion and sale of agricultural land. The cognitive interpretation diagram in Figure 14.2 also indicates an affirmative relation between surface water bodies and groundwater sources. Hence, if surface water bodies are improved through decreased inflow of pollutants, this will lead to recuperating the quality of groundwater available, thus improving the quality of drinking water. This improvement in water sources will also enhance the food security, as, currently, contaminated water is used to produce crops hampering not only the health of the locals but also of all the consumers (mainly the urban residents of Bangalore city).

14.4 Improving Water Security: The Way Forward

Sustainable water management and access to clean drinking water and sanitation for all has been recognized as an important benchmark of development, as given in Sustainable Development Goal 6 (SDG 6). The South Asian Association for Regional Cooperation (SAARC) too, in paragraph four of article III of its social charter, states that access to basic education, adequate housing, safe drinking water and sanitation, and primary health care should be guaranteed in legislation, executive, and administrative provisions. On the other hand, SDG 11 emphasizes making human settlements and cities safe and inclusive.

The Global Water Partnership's Framework for Action (GWP 2000) and the more recent *Asian Water Development Outlook 2007* assert that the water crisis is mainly a crisis of governance. Indeed, in peri-urban settlements in low- and middle-income countries, water supply and sanitation provisioning by local authorities leaves a lot to be desired. Poor governance in the face of population explosion and climate change in Indian and Asian cities alike only compounds the problem. Informal water markets and public–private–community partnerships emerge when piped networked water supply fails, and they play a decisive role in the management of water supply as shown by the examples of Orangi Township in Karachi and Dhaka.

Urban and peri-urban areas must work in synergy to enhance inclusive and sustainable urbanization and provide for integrated planning and management of sustainable human settlements in a participatory manner. Unplanned development, including unchecked water resource extraction, combined with variations in the climate have resulted in numerous indirect consequences within Manchanayakanahalli *gram panchayat* with wider implications on the area's water security, as highlighted by this study.

This study mirrors priorities set by Agenda 2030 by delineating a framework for planning based on the principles of collaboration and inclusivity in order to achieve the goals set by the SDGs and more specifically SDG 11. The framework indicated how anticipatory action research can be developed using citizen-centered scenario planning as a practical and potentially powerful tool. Participation of all stakeholders is the key to develop a citizen-centric design to identify issues to incorporate multiple stressors into the research process. This study captures local knowledge based within the communities and features how urbanization, along with climate change, has changed the lifestyle of this agrarian *gram panchayat*. Thus, the issues identified in a collaborative manner act as the foundation upon which effective solutions can be formulated. This chapter depicts how a collective will (Aguilar 2008) can be forged by mobilizing citizens and communities. In sum, responsive, inclusive, participatory, and representative decision making at all levels should be ensured to achieve Agenda 2030, as laid out in SDG 16(United Nations 2015).

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15

The Water Conundrum in India: An Institutional Perspective

Piyush Tiwari

15.1 Introduction

India is facing daunting water insecurity as the projected demand is likely to outstrip available supply by almost 50% by the year 2030 (Niti Ayog 2018). The demands for water of the world's sixth-largest and fastest industrializing economy and rapidly urbanizing society come at a time when the supply potential is limited, water tables are falling, and water resources are deteriorating fast due to exploitation and indiscriminate pollution (Shah 2013). Rivers and groundwater are polluted because untreated effluents and sewage are discharged into them unabated (Shah 2013). Over the last 70 years since independence, the per capita availability of water has declined. While these numbers hide inequalities in access, they do indicate growing pressure on this precious resource from various competing uses. The rising demand for and declining availability of potable water not only threaten sustenance, but also pose substantial risks to economic growth. With economic growth and population increases, demand for water is growing while entitlements of competing users remain unclear. The water resource distribution does not match the spatial demand, with some regions in the country facing droughts year after year, while others are inundated with floods. The geographical boundaries of states do not overlap with the river basin and, in the absence of well-defined mechanisms and institutional arrangements to share water, inter-state river disputes are common and often violent. Issues on sharing water resources have led to numerous inter-use, rural-urban, intra-state, inter-state, and international conflicts (see Paranjape and Joy [2011] for a review). These problems are only expected to grow due to climate change's impacts on the hydrological cycle. Some regions in India will see more instances of droughts, as precipitation patterns change, while others will witness floods, as the intensity of precipitation increases. The effects at the sub-basin level will be disparate and complex.

Nearly 85% of water in India is used by agriculture for irrigation, often inefficiently. Canals and groundwater are two irrigation sources, with the use of the latter having increased substantially; both have reached their upper use limits and current practices are impossible to sustain. The 2030 Water Resources Group (2009) argued that technical interventions will bridge the demand-supply gap by 2030. So, where is the problem? Unfortunately, the solution to water problems in India is not simply technical, but requires an understanding of the ecosystem and the institutional, political, and economic complexities that are involved in managing water resources (Araral and Yu 2013). There have been three major developments in clarifying and developing an institutional framework for water in India: the water paradigm in the Twelfth Plan which proposes management strategy changes; the 2016 Draft National Water Framework Bill; and the Mihir Shah Committee report, entitled 21st Century Institutional Architecture for India's Water Reforms, tabled in 2016. The 2016 Draft Bill has yet to be passed by parliament and adopted by states given that water is largely a state subject in the Constitution, except in the case of inter-state river basins. Another important development in increasing the awareness of water management among states is the recently launched Comprehensive Water Management Index (Niti Ayog 2018).

In this context, the objectives of the chapter are: (i) to briefly outline the complexity of the water problem in India; (ii) to present a theoretical framework for understanding water demand, supply, and management (the chapter assumes that all elements of this framework should function for sustainable management of water); (iii) to discuss the current status of water management in India in light of the theoretical framework; (iv) to outline recent policy and institutional developments in the water sector; (v) to present a brief review on key outstanding issues; and (vi) to address security and sustainability of water resource in India.

15.2 Complexity of the Water Problem

15.2.1 Water Availability and Demand

The water problem in India is complex. The total surface water potential in the country is about 1,869 cubic km, only 1,123 cubic km of which can be used (CWC 2010). On a per capita basis, water availability has declined from 5,177 cubic meters per year in 1951 to 1,588 cubic meters per year in 2010. According to the definition adopted by the UN

Food and Agriculture Organization, India is a water-stressed state.[1] The disparity at the local level is far starker. Of the 20 major river basins in the country, 14 are water-stressed and the situation is deteriorating due to increasing demands. Table 15.1 presents the demand for water for households and agricultural use by river basin. The availability of water for industrial and other uses has been calculated as residual, i.e., water availability minus the demand for households and agricultural use. The largest and most populated river basin of the Ganges will face a severe water shortage by 2050 (Araral and Wu 2016). The problem is exacerbated by seasonal and temporal variations in the availability of water during the year. Storage of water could ameliorate the variations. However, existing and planned storage (Table 15.1) has almost reached the maximum (Briscoe and Malik 2006) and this will not meet future needs if business-as-usual continues. Furthermore, the capture of so much water from the basin and loss of water due to surface evaporation has caused regional climate change, saline water intrusion, and water pollution problems as domestic and industrial effluents flowing into the basin from cities can no longer be diluted due to insufficient river flows (Ackerman 2012). Groundwater, which is a steady source of drinking and irrigation water, has also been exploited to the extent that many regions in the country are facing seawater ingression in coastal areas and groundwater pollution (Gaur and Amerasinghe 2011). Ironically, the focus of public investment for water resource development has been on surface water over the last 3 decades; consequently, groundwater has emerged as major source of water albeit entirely based on private investments (Shah 2013).

15.2.2 Climate Change

Although the scientific evidence is still being collected, climate change is likely to cause water stresses in several regions in the country. Gosain, Rao, and Arora (2011) argued that by 2050, most river basins would see an increase in precipitation. However, the extent to which an increase in precipitation would result in higher water availability would depend on the rate of evapo-transpiration, which will also increase due to a rise in temperatures. Increased precipitation and its intensity would have severe implications on sediment erosion. Most river systems would face higher sediment load. With climate change, instances of drought will also increase. Some of the major river basins would see a 5%–20% increase in droughts by 2050 despite increased precipitation (Gosain,

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[1] According to the Food and Agriculture Organization, per capita water availability of less than 2,000 cubic meters per year is defined as a water-stressed condition.

Table 15.1: River Basin Water Availability and Demand

Name of the River Basin	Population ('000,000)	Total Utilizable Surface and Groundwater (km^3)	Surface Storage Potential (km^3)	Total Surface and Groundwater Storage (km^3)	Per Capita Water Available, 2010 (m^3)	Estimated Water Demand in 2010 (km^3)					Balance Available for Industries and Other Uses (km^3)		
						Irrigation	Domestic	Total	Return Flow[a]	Net for Irrigation and Domestic	2010	2025	2050
Indus (up to border)	59.01	72.49	19.14	45.63	1,242	102.09	2.83	104.92	12.47	92.45	-19.95	-49.50	-71.81
Ganga	505.54	420.99	94.35	265.34	1,039	311.99	22.19	334.18	48.95	285.23	135.77	43.91	-24.25
Brahmaputra, Barak, others	49.71	59.07	52.94	88.01	11,782	14.52	2.73	17.25	3.64	13.61	45.46	41.31	37.72
Godavari	76.02	116.95	41.89	82.54	1,454	34.37	3.22	37.59	6.01	31.58	85.32	75.20	67.72
Krishna	85.62	84.41	49.61	76.02	912	42.85	4.28	47.13	7.71	39.42	44.98	32.32	22.94
Cauvery	41.27	31.3	12.96	25.26	518	16.13	1.98	18.11	3.20	14.91	16.39	11.59	8.01
Subernarekha	13.23	8.63	3.93	5.75	935	3.45	0.61	4.06	0.83	3.23	5.37	4.31	3.47
Brahamani and Baitarni	13.80	22.35	13.72	17.77	2,063	7.15	0.51	7.66	1.12	6.54	15.81	13.7	12.11
Mahanadi	37.45	66.45	26.52	42.98	1,786	26.32	1.52	27.84	3.85	22.99	43.51	34.79	29.05
Pennar	13.67	11.79	4.82	9.75	462	5.81	0.64	6.45	1.09	5.36	6.47	4.72	3.33
Mahi	14.78	7.30	5.21	9.41	746	5.07	0.62	5.69	1.00	4.69	2.61	1.12	0.01
Sabarmati	14.80	4.93	1.56	4.56	257	7.01	0.87	7.88	1.4	6.48	-1.58	-3.68	-5.23
Narmada	20.70	45.33	27.14	37.97	2,205	11.26	0.83	12.09	1.79	10.30	35.00	31.69	29.24
Tapi	20.85	22.77	12.26	20.53	714	3.89	1.10	4.99	1.27	3.72	19.05	17.86	16.96
West-flowing rivers from Tapi to Tadri	36.33	20.64	16.42	25.12	2,406	3.9	2.51	6.41	2.40	4.01	16.59	15.47	14.25

continued on next page

Table 15.1 *continued*

Name of the River Basin	Population ('000,000)	Total Utilizable Surface and Groundwater (km^3)	Surface Storage Potential (km^3)	Total Surface and Groundwater Storage (km^3)	Per Capita Water Available, 2010 (m^3)	Estimated Water Demand in 2010 (km^3)					Balance Available for Industries and Other Uses (km^3)		
						Irrigation	Domestic	Total	Return Flow[a]	Net for Irrigation and Domestic	2010	2025	2050
West-flowing rivers from Tadri to Kanyakumari	45.91	33.27	13.81	22.81	2,473	5.99	1.94	7.93	2.15	5.78	27.52	25.67	24.27
East-flowing rivers between Mahanadi and Pennar	33.25	22.11	4.24	13.24	677	21.01	1.43	22.44	3.25	19.20	2.90	-3.26	-7.84
East-flowing rivers between Pennar and Kanyakumari	63.29	25.93	1.38	10.58	260	24.21	3.49	27.70	5.21	22.49	3.21	-4.01	-9.35
West-flowing rivers of Kutch, Saurashtra, including Luni	31.10	26.21	9.59	20.82	486	22.46	1.61	24.07	3.53	20.54	5.66	-1.02	-6.15
Area of inland drainage in Rajasthan desert					0	18.27	0.68	18.95	2.37	16.58	-16.58	-22.04	-26.52
Minor river basins draining into Bangladesh and Myanmar	2.11	18.80	0.31	19.11	14,679	0.67	0.12	0.79	0.16	0.62	18.18	17.98	17.82
Total	**1,178.44**	**1,121.72**	**411.81**	**843.21**	**47,096**	**688.42**	**55.71**	**744.13**	**113.40**	**629.73**	**491.69**	**288.13**	**135.75**

[a] 80% of domestic + 10% of irrigation.

Source: Based on Gaur and Ameraasinghe (2012).

Rao, and Arora 2011). Instances of floods and flow levels will also change drastically. Current practices of designing water management systems that do not fully account for climate change would come under severe pressure (Mujumdar 2011).

15.2.3 Demand-Side Challenges

On the demand side, the largest consumer is agriculture, accounting for 85% of water use, followed by domestic (about 7%), industry (6%), and energy (2%) (Gaur and Amerasinghe 2011). Going forward, the demand from non-agricultural uses will rise at a faster pace.

Irrigation, the largest consumer of water, is also one of the most inefficient. The productivity of rice output per cubic meter of water consumption is 40%–50% lower in India than in the People's Republic of China (Tiwari and Pandey 2012). While major and medium-sized projects have added to the irrigation potential, it has not been realized enough to keep pace with demand. Consequently, the micro-atomistic approach of private groundwater development has led to a mushrooming of tube wells to pump out water without much concern for the lithological set up constituting the aquifer (Shah 2011).

Industry also uses water inefficiently, with sectors such as pulp and paper, textiles, food, leather (tanning), metal (surface treatment), chemicals and pharmaceuticals, oil/gas, and mining consuming the most. With economic growth, the water footprint of industry has increased substantially. Further, the footprint of industry-polluted wastewater discharged in rivers and other water bodies is substantial (nearly 70% of industrial effluent is discharged untreated), which causes immense damage to freshwater availability.

The situation is further complicated by inequitable access to water. The rules that relate to access and control of groundwater are based on common law doctrine of absolute dominion. Owners of land have generally been viewed to have the right to extract as much water as they desire from wells dug on their land, resulting in overexploitation of this resource.

15.2.4 Water for Irrigation

Irrigation is gridlocked between policy makers' perceptions and the ground realities. The focus of policy and public investment is biased in favor of canal irrigation, even though nearly 62% of irrigation is done using groundwater. Even the efforts aimed at reversing the deceleration in canal-irrigated areas by stepping up investment in last-mile projects have not yielded favorable results. In fact, the net irrigation command areas under canals have continued to decline (Shah 2011). Nevertheless, governments at the center and state levels have continued to construct large public irrigation projects. As the new canal projects are decreasing returns to scale, planners are overestimating their design command area and potential in order to justify them unrealistically. Irrigation departments have remained construction-oriented, with little incentive and capacity for management of existing systems (Shah 2011). Resulting poor management of canal systems has led to a shift toward groundwater irrigation. "Green revolution" policies that were implemented during the 1950s and later the 1960s, which favored high-yield crop varieties that required intensive and timely irrigation, only added to the meteoric rise in the use of groundwater for irrigation. This was complemented by cheap and unmetered electricity, and subsidized credits for irrigation dug-cum-bore wells. Groundwater-irrigated farms performed better compared to those that used other sources in terms of cropping intensity, input use, and yields. Equity-wise, groundwater is also relatively more equitable than surface irrigation, although recent trends toward deeper wells have favored richer farmers.

15.2.5 Rural Drinking Water

India has faced challenges in providing safe drinking water to its 700 million people living in 1.5 million villages. In rural areas, the problems associated with drinking water are inadequacy and poor quality. Programs that were initiated from 1972 onward to provide rural drinking water have created supply infrastructure covering 95% of the rural population. However, this was largely an engineering intervention without much participation from local communities. Consequently, government investments and programs have not been able to supply adequate good-quality water to rural households. Much of the rural drinking water is supplied by groundwater. Declining water tables in many regions and pollution of groundwater has rendered government schemes unsustainable. In many states, local institutions, that is, *panchayati raj* institutions (PRIs), which are responsible for the operation and maintenance (O&M) of rural water supply schemes, have faced capacity constraints and lack of financial resources. The top-down approach of these schemes with no or little involvement of PRIs makes it difficult for them to take over the O&M scheme. In fact, many PRIs have shown unwillingness in taking over the completed schemes (Planning Commission 2011). The lack of local ownership has resulted in poor maintenance. Furthermore, tapping of groundwater for irrigation and drinking purposes without any coordinated management has strained the resource greatly. The disconnect between the management of household water needs and sanitation compromises water quality.

15.2.6 Urban Water Supply

Shah and Kulkarni (2015) presented a typology of India's urban water system. According to their study, there are four stages in the development of urban settlements; the proportion of surface and groundwater use depends on the stage of development. When the settlements are small, groundwater use is significant; and as the settlement grows to become smaller cities, then to large cities, the share of surface water use increases. However, the share of surface water in total urban water consumption surpasses that of groundwater only when cities become very large. It does not mean that the groundwater volume decreases, only that a large share of further incremental growth comes from surface water use once groundwater extraction stagnates. The demand for additional water is fulfilled through long-distance transportation from rural hinterlands. In some large cities such as Bengaluru, where the surface water development has not been able to meet the needs, private tankers ferry groundwater from rural to urban areas.

15.2.7 Urban Drinking Water

The situation regarding the availability of urban household water is not very different than for rural households. Urban water in India is in a state of despair as is evident from various statistics such as the proportion of households that have piped connection, water availability per capita, and quality (Bhatnagar and Ramanujam 2011). Table 15.2 presents performance indicators for water utilities.

Table 15.2 documents water utilities' operational inefficiency and fiscal insufficiency. Assets created for water supply have deteriorated in quality over time due to continuous neglect. The focus of public agencies has been on asset creation with limited or no incentive for O&M. Institutional fragmentation with regard to policy making, financing, regulation, and service delivery has also contributed to the current state. There is a lack of alignment between the responsibility for investment, which is at the state level, and O&M, which is at the urban local body level. Dependency of urban local bodies for funds on higher levels of government undermines their motivation for effective asset management, service delivery, and cost recovery. Further, the capacity of cities to carry out water and sanitation services is also weak due to years of neglect. The problem is further complicated as several unorthodox water supply systems (such as private water tankers from

Table 15.2: Indian Water Utilities, Performance Indicators

Indicator	ADB 20 (2007)	SLB 27 (2009)
Production		
Water production (l/c/d)	240	225
Wealth group: rich		
Service		
Coverage	81.2 (incl. public taps)	66.6 (only direct)
Water availability (hrs/d)	4.3	3.3
Water consumption (l/c/d)	123.3	126.4
Efficiency		
Unaccounted water (%)	31.8	44.1
Connections metered (%)	24.5	49.8
Unit production cost (₹/m3)	3.4	5.7
Operating ratio	1.63	1.49
Breakdown of total operating costs:		
Power/fuel (%)	43.9	40.4
Personnel (%)	29.7	27.0
Repair and maintenance (%)	11.5	12.9
Staff/1,000 connections	7.4	8.4

Note: ADB 20 is based on 20 local bodies. SLB 27 includes the performance of 27 local bodies.
Source: MoUD's Service Level Benchmarking Databook 2008–09 and ADB Databook 2007.

peri-urban areas bringing water to urban communities) have emerged in the urban areas (Zerah and Jaglin 2011) as a consequence of unreliable and inadequate public water supply. These take a variety of forms: sophisticated systems in high-income localities that drop out of the public water supply to a range of strategies used by the poor to meet their water needs. Strategies of the poor for access to water include politician-mediated access to public systems, private operator and tanker suppliers, and NGO-supported collective water supply systems. These informal arrangements directly come into conflict with formal systems and undermine their potential for improvement.

15.2.8 Urban Wastewater

About 80% of household water is released as wastewater. Although the Central Pollution Control Board rules suggest that a town or city's municipality (or its water authority) is responsible for the collection and treatment of sewage, most of it remains uncollected due to inadequate infrastructure. Of the wastewater that is collected, only a small amount is treated. The rest flows into *nallas* and drains through which it is pumped into open water bodies, largely untreated.

Industry is a major consumer of water in urban areas; it is also an irresponsible consumer. Most of the effluent it generates is disposed untreated either in the municipal sewage pipes or in open water bodies (Shah 2011). Eventually all sewage generated in cities (largely untreated as municipal treatment plants in India only have the capacity to treat one-fifth of the waste generated) finds its way to rivers and other water bodies, making them unusable. One of the main reasons for inefficient use of water by industry is poor pricing of water. Industries pay three charges related to water: a levy that serves to raise resources for state pollution control boards, a tariff to local bodies or other supplier, and a cost of river or groundwater extraction. These charges are so low that they constitute a very small proportion of the cost structure of an industry (Aggarwal and Kumar 2011).

Given the pricing structure of municipal water in India, which is highly subsidized and does not reflect the marginal supply cost, it has been difficult to incentivize households or industry to use recycled water, even for non-drinking purposes. Hingorani (2011) estimated that the cost to municipalities of supplying freshwater is almost 2.5 times the cost of recycled water (secondary treated water). However, the option of recycling water is not exercised by households or industry due to heavily subsidized water tariffs.

15.2.9 Conflicts

Given the complexity of water resources and inadequate institutional arrangements, several trans-boundary, inter-state and intra-state conflicts have arisen in India, many of which have been violent. These can occur over equitable access, competing uses, dams and displacement, and privatization allocations (Paranjape and Joy 2011). India has lacked proper democratic, legal, and administrative mechanisms to handle various issues that arise with water, thereby leading to numerous conflicts (see Paranjape and Joy [2011] for a review).

The above discussion illustrates that the prevailing paradigm has not delivered the optimal outcome for sustainable water management in India. A discussion on institutional aspects is necessary to deal with the complexity of the water sector. Though different dimensions of the water sector are important, prioritization would still be required to determine how it should be governed, with ecological and equity aspects dominating, as these would ensure that the water resource is used sustainably and equitably.

15.3 A Framework for Analysis

The key characteristics of water described by Savenije (2002) are the following: (i) water is essential for life, economic activities, and the environment; (ii) water is non-substitutable; (iii) water is a finite resource limited by the amount that circulates in the atmosphere; (iv) water is fugitive as it flows with gravity; (v) water is a system following a complex cycle; and (vi) water is bulky, making carrying it tedious, if not impossible, as well as expensive.

The Dublin Conference on Water and the Environment articulated four principles for management of water. The first principle states that water is a finite, vulnerable, and essential resource, which should be managed in an integrated manner (ICWE 1992). An overarching consensus for water is that it should be utilized and managed sustainably; a question remains is how this should be done if the end goal is that human, economic and environmental needs must be met sustainably. Based on Tiwari and Hingorani (2014), Figure 15.1 presents a conceptual framework for understanding the water management institutional environment. The framework is a pyramid comprising seven blocks; a well-established lower block is necessary for the upper component to deliver efficiently. Each of these blocks could be further nuanced, but are presented here in their simplest form.

The first building block is the set of social norms concerning water. The historical and socio-cultural narrative that society has for water becomes the philosophical foundation for constitutional laws.

The second block is obligations to both a country's resources and its citizens. Given the characteristics of water, the foundation is the public trust doctrine (PTD), as opposed to "water as private property", which needs to be enshrined in the constitution. The PTD, which aims to protect water from degradation by preventing it from being transferred from public into private hands (Ivan 2011), has a constitutional mandate in India; however, this has not been explicitly codified by the legislation, causing ambiguities and irregularities in its interpretation. Article 21 in the Constitution states that "No person shall be deprived of life or personal liberty except according to procedure established by law". Those laws that conflict with fundamental rights named in the Constitution are voided (India Constitution, Art. 13[2]).

Citizen suits are the most rapid means to challenge actions that threaten fundamental rights (Takacs 2008). Courts have taken these rights seriously and have strengthened them with the PTD to protect citizens' environmental human rights (Takacs 2008). Under the Constitution of India, water has been interpreted by the courts as a right under Article 21—Right to Life. Given the characteristics of water as described earlier, it is appropriate to apply the PTD to this resource. Together, the PTD and Right to Life provide the constitutional basis on which policies and programs related to water management should be formed. While codification of the PTD for water and water as necessity to ensure Right to Life becomes the second block of the pyramid, the policies become the third.

The third block is the policies, which state the course of action required to deliver on constitutional obligations. These also guide the institution of laws, planning mechanisms, and programs.

The fourth block is legal/planning/programs. While laws are necessary to deliver on constitutional obligations, they take their guidance from policies. The management of water takes place within the national planning and legal system. Laws related to water operate within the national legal system. Planning systems for water management need to be coordinated across scales from national to regional to the local.

The fifth block is agencies, that is, different levels of government, including nongovernment organizations, community associations, and any others that are responsible for planning, development, and sustainable water management.

The sixth block is sustainable financing. A range of mechanisms that will comprise capital investment, funding for O&M of water infrastructure, user charges payable by consumers of water, financial mechanisms for efficient utilization of water, including wastewater treatment and revitalization of water resources, are necessary.

The seventh block in the pyramid for sustainable water management is users who are characterized by type of use, affordability, and nature of need for water (sustenance or economic). Water is necessary for survival and also for economic activities. Meeting these needs without compromising sustainability requires prioritization.

15.4 Examining Sustainable Water Management in India

This section applies the theoretical framework presented above to examine the institutional structure for sustainable water management in India.

15.4.1 Socio-cultural Narrative of Water: Block 1

Water has a supreme position in the Indian psyche. In its preamble, the Draft National Water Framework Bill 2016 states that *water is the common heritage of the people of India; is essential for the sustenance of life in all forms; an integral part of ecological system, sustaining and being sustained by it; a cleaning agent; a necessary input for economic activity such as agriculture, industry and commerce; a means of transportation; an inseparable part of a people's landscape, society, history and culture; and in many cultures, a sacred substance, being venerated in some as a divinity." It also states that "water in all its forms constitutes a hydrological unity, so that human interventions in any one form are likely to have effects on other.*

15.4.2 Water Rights in the Constitution of India: Block 2

The basis for addressing water sector complexities requires a clear understanding of rights associated with this resource. Although not explicitly stated in the Constitution, as discussed earlier, by judicial pronouncement, water is held in public trust for the community. Expanding this view implies that (i) economic or commercial use of water must not adversely affect the lives and livelihood of the community, and (ii) the PTD applies to all forms of water, including groundwater, which conflicts with its current legal status (Upadhyay 2011). Another important aspect of water from the constitutional perspective is the Right to Water, which relates to basic water requirements for life and is separate from its economic uses. By judicial interpretation, this is a fundamental right and the state has the responsibility to ensure that it is not denied to anyone (Upadhyay 2011).

15.4.3 The Policy: Block 3

The National Water Policy

India first developed a National Water Policy (NWP) in 1987. The policy did not suggest any major economic and institutional changes and soon became redundant. Revised in 2002, it recognized the importance of water for life, maintaining ecological balance, and economic and development activities of all kinds, as well as its growing scarcity. But it did very little in terms of setting the principles and objectives that could lead to sustainable use and required that states formulate their own state water policies and operational action plans while maintaining national consensus and commitment to underlying principles and objectives enshrined in the policy. The status is that only 11 states have finalized and adopted their own water policies. Three states adopted the NWP. Ironically, none of the northeastern states, which are endowed with huge water resources, adopted water policies.

A new NWP was introduced in 2012 with the objective of addressing problems with earlier policies (MoWR 2012). Recognizing the characteristics of water as a resource, the policy expressed the need to evolve a National Framework Law, "as an umbrella statement of general principles governing the exercise of legislative and/or executive (or devolved) power by the Centre, the States and the local government bodies . . . to deal with local water situation" (MoWR 2012: 4). The policy sets the principles for managing demand, enhancing availability, and enhancing water use efficiency through various mechanisms, including pricing. The policy emphasizes decentralization of project planning and implementation involving local governing bodies and water user associations (WUAs); it also emphasizes community involvement. Despite these ideological shifts, the engineering construction-oriented approach to water supply augmentation still underpins the policy.

There are three major concerns with these policies from the perspective of sustainable development of the water sector. The first relates to resource management, the second deals with the approach to planning in the sector, and the third is what it does for equity and empowerment.

a) Resource Planning

There are major ideological differences, and hence approaches, among policy makers and experts in their views regarding water resource planning and management. Opinion is divided over whether water is a socio-economic good or a necessity and constitutional right. This poses a challenge for the sustainable development of the sector, as convergence of these views at a policy level is often difficult. Parikh (2009), for example, recommends water resource management from the standpoint of augmenting supply through various government-led interventions like programs for rainwater harvesting and artificial recharge of groundwater, watershed development, expanding water storage capacity, interlinking of rivers, appropriate pricing, regulators, state-led WUAs, recycling, sewage treatment plant maintenance charges in urban areas, etc.

Others (see, for example, Iyer 2011) argue that the emphasis on supply-led water security approaches dominated by large projects is *status quo-ist*. The policy focus on further development of irrigation potential undermines the lessons that have been learned through the various five-year plans. Huge investments have gone into building canals, without adding much to the net area irrigated. Moreover, the history of canal irrigation in India indicates that there has been a substantial shift toward groundwater-based systems, which is irreversible and has undermined the relevance of large canal projects and policies (Shah 2011).

The reality is that these policies have been supply-oriented, and they attempted to meet demand by making more water available through large projects. The NWP 2012 attempted to reverse some of these trends by focusing on decentralized water management by proposing command area development, joint development of surface- and groundwater, etc. However, the large-project, development-oriented strategy for water management is still part of the strategy, albeit to a lesser extent than past policies. This approach is not conducive to the sustainable development of the sector for two main reasons. First, the demand projections based on which the supply-side investments are derived from the projections of population and preconceived notions about development and conceptions of the good life. Second, such an approach implicitly encourages inefficiency and waste in all water uses. The NWP recommends the use of non-conventional methods such as inter-basin transfers, as well as traditional conservation practices such as rainwater harvesting. Some of these options such as inter-basin transfers are highly expensive.

b) Approach to Planning

One of the reasons why India has not achieved optimal water resource management is its nationally centralized approach. The NWP suggests the development and management of water resources at a hydrological unit such as a drainage basin or a sub-basin level; however, in practice, this has not been possible. The policy further recommends the establishment of river basin organizations (RBOs)/sub-basin for integrated water resource management. However, in the absence of well-defined water rights to accommodate various uses across states and address the numerous conflicts that have arisen, it has been difficult for basin states to agree on RBOs. The MoWR RBOs are not effective, as they lack the necessary support from constituent states. The NWP recommends establishment of tribunals to resolve water-sharing disputes among states, but there is no concrete pathway on how this will work.

There are also problems with the planning and implementation of large projects that have been planned, approved, or initiated. Many of these hydro-projects are in the northeast of the country, with the intention that they would drive economic development. The justification for these large projects is weak. The NWP 2012 does not provide any guidance on how they should be identified or whether the philosophy of large-scale projects is tenable. By suggesting that all water projects, including hydropower projects, should include storage and should be multi-purpose, the policy is supporting the large-scale development approach of the past. The large projects in the northeast have been justified on the basis that only small areas are submerged due to these projects and hence their environmental impacts or impact on livelihood are limited. This grossly ignores how, with very little arable land available in the northeast, any loss of arable land is significant (Vagholikar 2011). In addition, submerging common areas, along with restricting access to catchment areas and forests planted to compensate for submerged forest areas, further affects community access to land and resources. Finally, direct and indirect displacement of culturally sensitive indigenous communities is large if viewed from the perspective of local population. The demographic issues are further compounded by large influxes of migrant labor. State-specific resettlement and rehabilitation laws do not adequately address the complex social and demographic issues and are primarily restricted to compensation issues (Vagholikar 2011).

c) Equity and Empowerment

Evaluated in terms of their impact, NWPs do not provide adequate measures for equity and empowerment. Earlier policies centralize the water sector, and while the 2012 NWP does emphasize decentralization, its scope is limited. In fact, an absence of a well-defined institutional architecture for cooperation between central/state/local bodies/ WUAs, with clear roles, responsibilities, and finances, could lead to responsibilities being transferred to local bodies or WUAs without adequate resources. The policy that the inter-basin transfer of water and resolution of inter-state water disputes should be guided by national perspective gives further ground to the view on centralization. A similar trend is observed at the state level. Establishing and empowering state-level independent regulatory agencies to develop water plans, as proposed in earlier policies, conflicts with the decentralization efforts as promoted through the establishment of WUAs.

15.4.4 Water-related Laws: Block 4

Laws are required to enable institutions to deliver on sustainable management of water resources while delivering on the right to water and to ensure that the distribution is equitable. When examining water laws in India from the rights-based perspective, three areas have received the maximum focus, that is, WUAs, water resource regulatory authorities, and groundwater management. However, there are still several gaps in these areas.

A range of laws has been enacted to empower farmers' participation in the management of irrigation systems and give them the right to water. Yet, the government's right to water is unchallenged, and its obligations to deliver water to WUAs are rarely legally binding (Upadhyay 2011). Further, although WUAs have the right to obtain information in time about water availability, as well as to receive water in bulk from the irrigation departments for distribution among users based on equity principles, and to receive water according to an approved time schedule, these rights are meaningless as long as the remedies in cases where irrigation departments do not honor their commitments are not specified. Irrigation departments have failed to deliver quality services. Much of the focus of states and irrigation departments is on capital expenditure in construction of new medium-sized and large irrigation infrastructure. O&M is ignored and the accountability of irrigation departments to farmers is minimal as the service fee is either very low or has been abolished since collection was low (Shah 2013).

In India, in order to ensure that water is equitably distributed, independent water resource regulatory authorities have been set up in Maharashtra, Andhra Pradesh, and Uttar Pradesh to oversee water entitlements by designated river basin agencies. The authorities are also responsible for fixing the criteria for trading of water entitlements or quotas. The problem, however, is that this has created a system where entitlements exist without corresponding obligations to ensure one receives them.

In the case of groundwater, existing rules of access and control are still based on common law doctrine of absolute dominion. Landlords have the right to take as much groundwater as possible from wells dug on their land, even though they do not own this resource. As discussed by Shah (2013), in law, distinctions are made between defined and undefined groundwater channels. Groundwater that does not have a defined course is not subject to same rules as flowing waters in rivers or streams. However, groundwater that flows in a defined course, as per case law, is subject to the same rules that are applied to rivers or streams. This has been interpreted to mean that landlords can access as much water as they want so long as this does not affect the application of the water for riparian users "in the exercise of either their natural right or right of easement" (Shah 2013: 50). Recent court rulings, however, have expressed that "deep underground water" is the property of the state under the doctrine of "Public Trust" and the holder of the land only has user rights.

These rulings notwithstanding, appropriate legal, policy, regulatory regimes for controlling the use of this resource do not exist. The model legislation for groundwater regulation prepared by the Central Ground

Water Board mainly proposes regulation of overdrafts, but does not deal with the larger issues of community rights over groundwater and tradability of private rights. A possible option to better manage groundwater is to move away from its absolute private ownership to a government-administered permit and/or licensing system for extraction. Although this is part of the model legislation that was introduced in 2016, it has yet to be adopted.

Past laws related to groundwater that focused on aspects such as restrictions on depth of wells, and declaration of conservation and protection zones had limited implementation success. However, these laws have avoided the most important question about the legal status of groundwater itself (Upadhyay 2011). The Draft National Water Framework Bill 2016 ameliorates the situation by emphasizing that, "water is the common heritage of the people of India, held in public trust, for the use of all, subject to reasonable restrictions, to protect all water and associate ecosystems. In its natural state, such as river, stream, spring, natural surface water body, aquifer and wetland, water is a common pool resource, not amenable to ownership by the state, communities or persons" (MoWR 2017). The bill has yet to be passed by parliament and adopted by the states.

15.4.5 Agencies: Block 5

Although a range of institutions govern the water sector, there is fragmentation with regard to their role and involvement. For example, MoWR is the principal agency responsible for water in India, but water pollution does not fall under its purview, nor does the industrial use of water. The Ministry of Industry is concerned with the planning and development of water resources for industrial use, but has no mandate to control or regulate the water use by industries. The Central Ground Water Board/Authority is meant to regulate the groundwater quality and quantity in the country; it has not achieved much success in regulating either. The Central and State Pollution Control Boards regulate industrial water pollution and charge water levies based on the amount of wastewater discharged, but they have no mandate to control sourcing of water from various sources. Unless all aspects of water use by industry are regulated by one agency, it will not be possible achieve either water conservation or pollution control in the sector.

In the case of urban water, although the responsibility for supply lies with the local bodies, state institutions (parastatals) are actively involved in the construction, management, and often delivery of water services in many cities. In the irrigation sector, due to increasing financial burdens for the expansion of surface irrigation systems, insufficient water charges and their poor recovery, and difficulties in meeting requirements, the government decided to involve farmers through participatory management. NWPs have explicitly provided for a participatory management approach involving not only the various government agencies but also the users and other stakeholders. Policies further propose that the WUAs and local bodies would be involved in the O&M and management of water infrastructures at appropriate levels; eventually, the management of such facilities would be transferred from the government departments to the user groups and/or local bodies. However, the evidence with regard to the ability of the WUAs to improve systems management has been inconclusive.

Even these public-private partnerships have not worked as intended. A study of WUAs in Andhra Pradesh, Maharashtra, and Gujarat finds that there have been substantial differences in the way they were instituted, their scope, and hence their performance (Gandhi and Bhamoriya 2011a). Further, the participation of farmers in WUAs has remained low and the performance of these institutions in relation to equity in distribution is mixed (Bassi, Rishi, and Choudhury 2010). It may therefore be inferred that the large-scale impact of these institutions on restoring the canal irrigation system is limited.

There are a number of shortcomings in the existing regulatory framework that have implications for efficient performance by institutions. For example, in cases of drinking water supply, though the legal bases like the fundamental Right to Water exist, a binding framework for realizing the right is lacking. The government has attempted to fill the void left by the absence of legislation through secondary instruments such as supply programs, but this has created a system of planning and execution of projects by government departments without the participation of the legislature. Additionally, the inconsistencies between the binding legal principles and the secondary instruments have caused problems. For example, the characterization of water as an economic good in the secondary instruments conflicts with the principles of water law. A fundamental right is by definition not subservient to market forces. Further, water is a public trust and the Supreme Court has specifically asserted that this cannot be alienated, thus making water impossible to be labeled as an economic good.

15.4.6 Financing Management of Water: Block 6

Financing for water management has been oriented toward large capital investment. States compete for capital investments in new major and medium-sized infrastructure projects, with central and/or state governments ensuring water security by building large dams, storage facilities, large embankments for flood control, canals, and transporting water to cities over large distances to meet rapidly urbanizing India's needs. The upkeep and maintenance of water infrastructure has been poor, which, as discussed earlier, leads to loss of water. In the case of irrigation, the revenues from water do not even cover 10% of the O&M cost. The low water charges and poor collection efficiency for rural and urban water use has led to lack of interest and funds for O&M and accountability of government agencies toward users. Inappropriate pricing of water has led to exploitative use by those who have access. Consequently, a large part of water infrastructure is subsidized by the exchequer. Though the estimate of the total water subsidy is not available due to incomplete data, it is evident that a large part is spent on irrigation projects (Palanisami et al. 2011).

Water pricing is a key tool for efficient water allocation and conservation. Unfortunately, water prices are rarely efficient and rates are still subsidized due to political obligations. A review of the political conflict between Tamil Nadu and Karnataka indicates that the cause is artificially low water prices, which have led to higher demand for irrigation in both these riparian states in the same season (Ghosh and Rachuri 2011).

In the urban context, water pricing is based on the average cost of service and is also influenced by affordability concerns and political interference. Thus, there is a wide divergence between water tariffs on one hand and O&M and capital expenditure on the other. A pricing strategy that would signal water utilities to provide improved services and users to use water efficiently is elusive. There is effectively no price for groundwater even though it is extracted from peri-urban areas and sold illegally in urban areas (Prakash, Singh, and Narain 2011). In addition, a pricing strategy reflecting the marginal cost of water will create demand for recycled water for use by households and industry. This will not only reduce the reliance on freshwater sources, but will also ensure round-the-clock supply.

Sustainable water management requires budgetary support, private sector financing particularly where the motive for water use is economic, strengthening of user charge determination and collection, and also incentives and fines for promoting efficiency.

15.4.7 Users: Block 7

The requirements of four categories of water users—households, irrigation, industries, and commercial and others—are philosophically different. The right to water does not imply that the availability of water for households should be the same as for industry, or that for small farmers should be on same basis as large ones. The requirements are insatiable and since water is a limited resource, they need to be prioritized, which has been missing in water harnessing and allocation mechanisms. Some policies unrelated to the water sector have had unintended consequences, an example being the power subsidies for the agriculture sector. On the one hand, power subsidies fueled the green revolution in India, which improved agricultural productivity; on the other hand, they led to the depletion of water tables since much of the resulting irrigation was groundwater-based, stemming from subsidized electricity that permitted excessive use (Shah 2013). Although the demand for water by industry is growing, as shown in Table 15.1, it is nevertheless an irresponsible user of water. A large proportion of effluent from industry is discharged untreated. Currently the mechanism for managing industrial effluent is the Water (Prevention and Control of Pollution) Cess Act 1977, which is a tax levied on a volumetric basis on discharged effluent water. These charges have not provided disincentives for industry in reducing its water footprint, since the volumetric basis ignores the degree of severity of pollutants in discharged water, which benefits highly polluting industries.

The foregoing discussion clearly indicates that the water resource management framework is very weak in India. There are challenges at all levels, and this is evident in the state of the water resource, as discussed in section 15.2, which, if the current situation continues, is threatened in terms of its sustainability.

15.5 Management of the Water Sector

The management of water on the user side has been poor. Although wastewater recycling and rainwater harvesting offer immense potential, they have not been fully exploited.

a) Wastewater Recycling

Technologically, wastewater recycling offers immense potential for becoming a viable and practical solution for non-potable water uses. The costs of recycling have reduced dramatically, particularly for industrial use, and although they still may be slightly more than the tariffs charged by municipalities on freshwater supply, the reliability of recycled water makes this a viable option. There are cases where large industries, forced by lack of freshwater supply from municipalities, have resorted to recycling (Hingorani 2011). Constraints that industries face in setting up their own recycling plants include (i) capital costs, which means that, for scale economies, recycling plants make sense only for large industries or clusters of industries; (ii) access to sufficient sewage at a reasonable cost; and (iii) sufficient land (Hingorani 2011).

Local bodies, for their part, can supply sewage-treated water to industries, but some have been reluctant to forego the revenue (due to higher tariffs) accruing from supply of industrial water. They are far more willing to invest in supply augmentation projects (as the capital cost is met through state and/or central government grants) than in wastewater recycling. Moreover, the market for recycled water has yet to be created. The use of recycled water by large industries (including power plants) located near urban areas should be mandated. Tariffs should reflect the opportunity cost of freshwater to incentivize the use of recycled water (Hingorani 2011).

Local bodies themselves treat very little sewage despite rules to the contrary. The total installed national treatment capacity is only 19% of the total sewage generation (Kamyotra and Bhardawaj 2011). The pollution control boards cannot penalize local bodies who violate the disposal norms. Given the weak financial capacity of local bodies, there is a need to incentivize them to construct sewage treatment plants. Grants or loans are one option and could be used to fund a pipeline network (Kamyotra and Bhardawaj 2011). For sustainability, it is important that there is an orientation toward O&M cost recovery and efficiency. The provision of grants could mandate that all bulk water supply projects be complemented by an increase in sewage infrastructure. Incentives and funding should be tied to reaching certain treated water reuse benchmarks.

Given the high cost of sewage networks, decentralized treatment plants are being encouraged. Regulations in some cities mandate that all new housing colonies set up treatment plants to ensure management of wastewater. To further incentivize the use of recycled water, tariffs for domestic uses should be devised such that the consumption of freshwater is charged higher while treated water is supplied free of cost. All these regulations and incentives would need to be supported by strong awareness programs on the use of recycled water.

b) Rainwater Harvesting

Rainwater harvesting has huge potential to replenish and recharge groundwater. Although the 2002 NWP recommends the development of rainwater harvesting systems and the last two Five-Year Plans allocated budgets for watershed development programs, the extent of rainwater harvesting is minuscule. While it is important that laws requiring rainwater harvesting are strengthened, local solutions for better groundwater management should also be encouraged. The check dam movement in Gujarat is an example where a number of check dams have been constructed by public efforts and nongovernment organizations to store water during monsoons, thus recharging aquifers but also filling up wells for use during lean periods. Decentralized traditional methods of rainwater harvesting should be encouraged, as these have provided local solutions to the scarcity of drinking water in some regions of the country.

15.6 Recent Developments

15.6.1 Draft National Water Framework Bill 2016

A new Draft National Water Framework Bill 2016 was introduced in Parliament for approval in 2016. Water in the Indian constitution is in the state list (Entry 17 in the State List of the Constitution), except for issues concerning inter-state river basins (Entry 56 in the Union List of the Constitution). The responsibility for development and management of inter-state river basins is with the central government and it is obligated to deliver on this through an authority for each basin. State governments will manage intra-state river basins.

The Draft National Water Framework Bill is cognizant of current concerns in management of water resources in India and legal lacunae and makes following provisions:

- The bill includes provides for the Right to Water for Life, which requires that every person have sufficient, safe, accessible household water for life.
- The bill also states “The State at all levels holds water in public trust for the people and is obliged to protect water as a trustee for the benefit of all” (MoWR 2017: 7).
- River rejuvenation is an important part of the bill requiring appropriate funding to ensure “continuous flow in time and space including maintenance of connectivity of flow in each river streams”, “unpolluted flow”, and “clean and aesthetic river banks” (MoWR 2017: 8).
- All states have equal rights over the use of water in a river basin, provided such use does not violate the Right to Water for Life for any person.
- The bill requires states to rejuvenate depleted and stressed aquifers within their jurisdictions, as this is vital for river flows.

- An important paradigm shift is moving away from harnessing water resources toward sustainable management and "sustaining ecosystems dependent on water".
- The bill requires states to prepare water security plans for, "attainment of sufficient quantity of safe water for life and sustainable livelihood for every person", and, "to ensure water security even in times of droughts and floods" (MoWR 2017: 15). The plans should include appropriate incentives and structures for efficient water utilization and management.
- The "Model Bill for the Conservation, Protection, Regulation, and Management of Groundwater 2016" has been proposed. Key features are implementing the "principle of subsidiarity", public doctrine trust principle for groundwater, and management of ground and surface water for conjunctive use.
- The bill requires that appropriate service-level benchmarks be adhered to for water supply, sanitation, solid waste management and storm water drainage. Urban water supply should be metered and priced while ensuring "sufficient quantity of water and sanitation free of cost as part of realization of the right to water for life" (MoWR 2017: 21).
- For irrigation water management, the bill emphasizes a participatory approach with statutory powers for WUAs to collect and retain part of the service fees. The conservation, management, and regulation of water shall be based on principle of subsidiarity.
- Given industries' poor management of wastewater, the bill requires an annual audit of its use and a plan to reduce water footprint. The bill also requires industries to increase the use of recycled water. Appropriate water-pricing mechanisms that will include efficiency cost and capital cost are also proposed.
- The planning and management of water resources has been constrained by lack of data; in this regard, the bill proposes a comprehensive data management system.

The Draft National Water Framework Bill 2016 is a progressive umbrella statement of, "general principles governing the exercise of legislative and/or executive (or devolved) powers by the centre, states and local governing bodies" (Ghosh and Bandopadhyay, 2016: 20). The bill has been able to address several water resource challenges and will provide the legal basis for institutions, policies, and programs for sustainable water management. However, the bill still needs to be passed by the parliament. In addition, states need to adopt the Framework Bill for it to become an effective legal instrument.

15.6.2 The 21st Century Institutional Architecture for India's Water Reforms

Another major development has been to reform the planning and governance system for water resource management. A committee chaired by Mihir Shah submitted its report "21st Century Institutional Architecture for India's Water Reforms" in 2016 that proposed that two apex institutions—the Central Water Commission (CWC), responsible for planning, development, and management of surface water, and the Central Ground Water Board, responsible for groundwater—be combined to create a new CWC since both entities have taken a reductionist engineering approach to water management. Further, the Commission proposes a different organizational structure for the new entity, which will instill a move away from engineering to a more comprehensive approach for water management in line with the Draft National Water Framework Bill 2016.

15.7 Unresolved Issues

Despite the progress made by the National Water Framework Bill 2016 and the Mihir Shah Committee toward a prudent institutional architecture for sustainable water resource management in India, there are still some unresolved issues.

Ghosh and Bandyopadhyay (2016) argued that water security as espoused in the National Water Framework Bill and Mihir Shah's report is still based on a neo-Malthusian focus on ensuring Right to Water for Life and insulating the agrarian economy and livelihood system from pernicious impacts of droughts, floods, and climate change. They argued that this is myopic and proposed that reforms related to water resources should be based on environmental security, defined as a "state of absence of conflicts in complex and interconnected relations in and between the biological, social, economic and cultural processes of human societies and the natural environment" (Ghosh and Bandyopadhyay 2016: 22). An irresponsible anthropogenic intervention in the hydrological cycle threatens environmental security. The draft National Water Framework Bill emphasizes better water resource management, but the objective should be expanded to encompass environmental rather than just water security.

The institutional architecture presented in the draft National Water Framework Bill and Mihir Shah Committee Report strengthens WUAs' involvement in planning and management of water resources by giving them statutory powers to collect and retain part of irrigation service fee. Joy (2016), however, argued that for a more modern institutional structure, which would be much more than a National Water Commission, and would involve participatory institutions at various scales. WUAs in their current form are very restrictive, and these eight primarily canal-based irrigation associations do not deal with non-irrigation needs and users. The institutional framework that Joy (2016: 32) addressed revealed a hierarchical structure with, “integrated water users’ association at the primary level … their federations at different scales for management functions, and micro-watershed, sub-basin and basin organizations from all stakeholders to perform governance functions such as water allocation, pricing and conflict resolutions.”

Despite its merits, the separation of the model bill for The Conservation, Protection, Regulation and Management of Groundwater 2016 from the draft National Water Framework Bill 2016 casts doubt on how water resources will be managed. Despite the interconnectedness of river basins with groundwater, and emphasis of this in the National Water Framework Bill 2016, the river basin plans, that is, the core of the framework bill, have not been integrated with the groundwater bill (Srinivasan 2018). Further, the emphasis of proposed river basin organizations seems to be largely for the preparation of master plans, which, according to Ghosh and Bandyopaghyay (2016: 23) is “risky and provides an opening for technocratic monopoly”. The relation between river basin organizations and the proposed CWC is also not clear.

While the draft National Water Framework Bill 2016 proposes participatory planning to manage water resources, Lele and Srinivasan (2016: 50) are concerned that the proposed CWC could become a monolith institution without much local participation and argue that it, “could fruitfully focus on integrated data and science for helping water managers and policymakers in an intensely contested and changing water landscape” without getting directly involved in planning or regulation. Nilekani (2016) emphasized this concern and argued that open platform technologies and innovations that are already happening on the ground should be encouraged through mechanisms such as publicly funded open data platforms. This will enable people to manage water resources at the grassroots level.

One other missing aspect in the Framework Bill and Mihir Shah committee’s report is the changing cropping that is an outcome of water-intensive patterns. Dharmadhikary (2016) argued for a greater emphasis on aligning cropping patterns with the agro-climatic characteristics of each region.

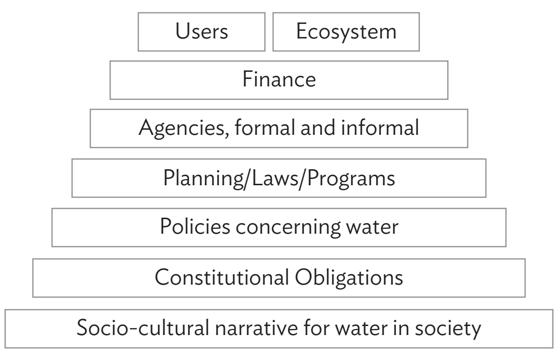
The criticisms of experts on Mihir Shah committee’s report illustrate the complexity faced in reforming institutional architecture for water resource management in India. Shah (2016: 61), in response to these criticisms, explained, “Only through this comprehensive shift in the paradigm of water governance in India can we come to grips with, and find sustainable and equitable solutions to, the growing water crisis facing India".

15.8 Conclusions

The water situation in India is catastrophic with surface and ground sources depleting and degrading, demand for water growing unabated, weak institutional architecture to plan these resources, lack of capacity in different institutions, and lack of human and financial resources, resulting in a water resource management system that is completely defunct. The top six blocks of the theoretical framework (Figure 15.1) for sustainable water resource management are dysfunctional. This section partially summarizes select points that have emerged to ameliorate the current situation.

There has been a substantial change in the country's water resource agenda, with the current view taking a holistic approach in contrast to the previous emphasis on supply-side, reductionist engineering. Given the threat to the security and sustainability of water resources in India, there is an urgent need to review the policy, regulatory, and institutional framework, water resource development, use and management practices, and incentives and penalties afresh. The draft National Water Framework Bill 2016 is an important first step in rebuilding the bottom two blocks of the theoretical framework (Figure 15.1).

Figure 15.1: A Conceptual Framework for Sustainable Management of Water Resources



Source: Author.

Technical water security opportunities are only possible if an appropriate environment for their implementation exists. Most opportunities for the efficient use of water exist in the agriculture sector, which is the largest consumer of water, but a highly inefficient user. In future, domestic and industrial users will put increasing claims on already stressed water resources, which will be affected by climate change. Water is managed and used locally, with numerous dimensions that relate to constitutional rights, user entitlements, equity and economics, the environment, and engineering. The draft National Water Framework Bill 2016 needs statutory backing to be legally binding. This is necessary to balance different dimensions of water resource management and to institute a shift from a supply-focused, top-down approach to a more local, participatory approach based on the subsidiary principle. A balance between supply-side and demand-side measures is necessary, evolving as a bottom-up approach. This approach would emphasize decentralized water resource development and management, wastewater recycling, and rainwater harvesting.

A clear articulation in the constitution of a PTD for water and Right to Water for Life is necessary to ensure water security and equitable availability. The PTD, which should govern all surface and ground water resources, will be a shift from the colonial notion of water as a private property to a resource held by the state on behalf of the community. The Right to Water, which has been interpreted as fundamental by various judicial pronouncements, needs an accompanying regime. At the same time, the quantity and quality of water for life needs to be unambiguously defined. There is also a need for an enabling framework that states which uses of water are a matter of rights and which are considered an economic good.

Any water-related activity in any part of a river basin, whether large projects such as dams or small projects such as water harvesting structures, impacts other parts of the basin. From a planning and execution perspective, the appropriate unit is a river basin. In this context, it is necessary that river basin states should come together and establish authorities. The O&M of project assets and service delivery should be left to local institutions like WUAs, PRIs, and urban local bodies. It is also necessary that the rights and obligations of institutions, at different levels, be clearly specified. The existing institutions need to be streamlined. The Mihir Shah committee proposes to merge the CWC and Central Ground Water Board into a facilitating, knowledge-based National Water Commission (Shah 2016). This will require that other ground-up institutions take substantial responsibility for management of water resources by strengthening or merging existing institutions or forming new ones where necessary. Mechanisms to enhance accountability and user participation need to be inserted into the institutional structure. At the same time, institutions would need to be transparent and accountable at all levels.

To improve the financial viability of the sector, water resource development should shift to (i) better maintenance and upgradation of existing water assets, and (ii) small, decentralized, local augmentation projects involving harvesting and watershed development. Where a large project is selected, it should be done only after a careful assessment of all options and the impact of project on the environment, people, and their livelihoods. Projects should be evaluated carefully to identify those segments where cost recovery is possible and those where cross-subsidy or grants are required. It is also necessary to identify the form and extent of subsidy and obligation on the level of government for various water resource development projects. The fiscal support should be evaluated with due considerations to obligations under the Right to Water.

At the same time, the capacity and capabilities of agencies (such as municipalities, irrigation departments, pollution control boards, PRIs, WUAs) involved in O&M of water assets, service delivery, and monitoring of water resources need to be substantially strengthened. This would require the development of a detailed information system that would cover complete resource mapping (availability, use, quality, seasonality in availability, meteorological data at an appropriate hydrological unit, state, city, village levels); asset mapping (level and condition); socio-economic information at various levels; and cropping and irrigation patterns. There is also a need for a national clearing house to collate and provide information on good water resource management practices (traditional and non-traditional) to help agencies.

Regarding irrigation, the focus of development projects needs to shift from large canal-based surface irrigation projects to an optimal mix of large and decentralized irrigation projects. This would also entail use of surface and groundwater resources. Mechanisms that incentivize efficiency and technological options such as drip irrigation would have to be instituted. The problem, however, is that these technological options come at a cost. Given that water is an economic input in industrial production, one option would be for industries to subsidize the cost of efficiency improvement technologies/programs in the agriculture sector.

In the urban context, one way to improve service delivery, and enhance transparency and accountability, is by corporatization of water utilities. Poor pricing and recovery have led to weak local government finances, which further impede the development and efficient delivery of water. There are many institutional and operational hurdles that make financial sustainability difficult. Chief among them is the neglect of performance orientation in decision making and lack of performance data. The Government of India has recently introduced service-level benchmarks for urban water utilities that will provide data to develop plans for performance and service improvements.

In addition, institutional changes that integrate planning, capital investment, and service delivery functions and assign them to urban local bodies are required since accountability and functional autonomy are necessary for customer-focused service delivery. At the urban local body level, ring-fencing or corporatization would help in improving the services. In this scenario, smaller urban local bodies would be able to join hands voluntarily to achieve economies of scale. Moreover, legal barriers, in particular the link between land tenure and service provision, have prevented expansion of water services to slums and squatter settlements. A consequence has been that the recipients of existing subsidies for the sector are not the poor. Reform efforts, in particular the Jawaharlal Nehru National Urban Renewal Mission (JNNURM), brought in the thinking about better service delivery, public-private partnerships, and innovative mechanisms to serve the poor and larger urban reforms. However, when one looks at the projects funded by JNNURM, they are traditional supply augmentation schemes. A paradigm shift that focuses on failures in distribution networks has not happened. This has also meant that Indian cities have been unable to engage with small-scale providers, despite their role in impoverished communities.

Adopting a corporate approach would allow utilities to run water services reliably and efficiently in a business-like manner without political interference. This, however, should be done while ensuring that peoples' Right to Water and universal service obligation of utilities are protected.

Even for the management of industrial wastewater, the approach has mostly been legislation-based, rather than using pricing mechanisms. The Central Pollution Control Board and state boards are empowered to prevent, control, and abate water pollution. But regulations require all polluters to meet the same discharge standards, thereby rendering the regulations inefficient. The use of market-based instruments in the form of fiscal incentives for pollution control has been limited. Even where they are specified, in the form of tax concessions on the adoption of pollution control equipment, they are for specific abatement technologies and activities, thus leaving no incentive for innovation. There is also some evidence of informal regulation of polluting industries through consumer and market behavior (because consumers have started demanding green-rated products), legal action undertaken in response to public interest litigations filed by locals affected by pollution from industries, and civil society protests forcing industries to comply with regulations.

Finally, water pollution needs to be controlled through market-based mechanisms like taxes on polluting industries, tax concessions for adoption of abatement technologies, and pricing mechanism-induced recycling. Mechanisms that act as informal regulation such as green ratings should also be promoted. Pollution control boards need to be transparent and accountable to affected people. Stringent enforcement of regulations, such as treatment of sewage water by local bodies and compliance monitoring, is necessary.

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16

Water Security Assessments in Central Asia: Research and Policy Implications

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16.1 Introduction

The Second World Water Forum in 2000 adopted the Ministerial Declaration of The Hague on Water Security in the 21st Century. Since then, the concept of water security has been increasingly used in both policy and academic communities (Zeitoun et al. 2013). In the policy field, the Global Water Partnership (GWP) and the World Economic Forum promoted water security (GWP 2000, 2012; Waughray 2011). It was also taken up by the 1st Asia-Pacific Water Summit, which featured as its theme Water Security: Leadership and Commitment (Cook and Bakker 2012).

In academia, researchers across a variety of disciplines have been focused on the water security concept from different angles. The social disciplines emphasize human welfare and security, while the natural sciences focus more on hydrological balance and natural hazards. The different policy and research interpretations also impact efforts on how to measure water security and the means for such an undertaking (Cook and Bakker 2012; Zeitoun et al. 2013).

In Central Asia, the notion of water security has evolved in the decades following the dissolution of the former Soviet Union. All Central Asian countries apart from Afghanistan were part of the former Soviet Union, where water security was understood as large-scale engineering solutions concentrating on surface water management for irrigation and hydropower. A balance between managing water resources for hydropower and irrigation was sought mainly by classifying Central Asian countries according to their hydrological position in a complex system of river basin networks.

The upstream countries of Afghanistan, Tajikistan, and the Kyrgyz Republic comprise the water sources of the two major rivers, Amu Darya and Syr Darya, and contribute most of their discharge. They therefore are often considered the "water towers" of Central Asia (Diebold and Sehring 2012). The downstream countries of Turkmenistan, Uzbekistan, and Kazakhstan are situated on extensive plains with diverse land cover ranging from desert to grasslands, where most of the water resources are used for irrigation, and they are also endowed with abundant hydrocarbon (coal, oil, gas) resources.

The five post-Soviet countries in Central Asia are in the process of completing their nation-building efforts. Immediately after the collapse of the former Soviet Union, water experts from these countries gathered and initiated joint water management mechanisms to tackle the problems of assessing and securitizing the water resources belonging to each state. The role of water professionals reflected a technical and managerial perspective of water security that prevailed until the mid-2000s which attempted to allocate resources based on water discharges of the major river basins (Abdullaev et al. 2010).

However, major concerns were raised by all states to defend their own water shares. In addition, at the domestic level, competition between foreign affairs ministries and line ministries on what constitutes national interest eventually led to the replacement of water officials with foreign ministries leading negotiations. The negotiations, meetings, and other interactions on water-related themes among Central Asian states became the theater for conflicting security priorities. The downstream countries were concerned with addressing water delivery for agriculture and food security objectives, whereas upstream countries with poor endowment of fossil fuels were desperate to increase hydropower production for energy security. These conflicting priorities have become major obstacles for water cooperation in the region. However, there was seemingly broad consensus that national water security offered economic leverage to all Central Asian countries. Much of the current focus in Central Asia and Afghanistan is on the empowerment of national economies and accessibility to natural resources by emphasizing hydrocarbons and freshwater systems.

In the case of Afghanistan, continuous wars since the late 1970s have identified water security with the need to possess water resources for the survival of the conflicting powers. Control over the water resources in war zones of Afghanistan was often seen as an opportunity to secure accessibility and deprive opponents from gaining access to the vital source.

In this study, we attempt to identify how the notion of water security has been elaborated in the research literature of the period after independence (1992–2018) for Central Asian countries, and the same period for Afghanistan. We apply an assessment approach to evaluate the role of different dimensions in the structuring of the water security concept in Central Asia. We adopt the framework introduced by the Asian Development Bank (ADB 2013, 2016) for the evaluation of water security in Asia, including Central Asia. This framework is based on five dimensions: household, economic, urban, and environmental water security, as well as resilience to water-related disasters.

We further explore if potential features of the research institutes and authors identified along the literature review could affect the selection of particular security dimensions. We conduct a multinomial regression analysis to examine whether the significance of the five security dimensions (dependent variable) could be potentially influenced by the origin of the institutes represented in the literature review, the authors' origin, and the type of research organization (independent variables). The study findings are compared with the current policy dialogue on water security held through different schemes (such as ministries, regional organizations) between the Central Asian countries.

16.2 Water Security Concept and Dimensions in Central Asia

A number of research and policy-relevant definitions have attempted to address all the dimensions and diversity emerging from the water security notion in the last decades. For instance, Cook and Bakker (2012: 97) identify "four interrelated themes [that] dominate the published research on water security: water availability; human vulnerability to hazards; human needs (development-related, with an emphasis on food security); and sustainability."

In a broader manner, the Global Water Partnership (GWP 2000: 12) notes that "water security, at any level from the household to the global, means that every person has access to enough safe water at affordable cost to lead a clean, healthy and productive life, while ensuring that the natural environment is protected and enhanced." Similarly, Grey and Sadoff (2007: 545) perceive water security as the "availability of an acceptable quantity and quality of water for people and environment at an acceptable level of water-related risks to people, environments, and economies."

These different understandings are also reflected in different indicators that were developed to operationalize water security. In all cases, water security is perceived as a very complex concept with both hydrological and social components interacting with each other, which makes the development of indicators aimed at simplifying and distilling information challenging. Inevitably, the choice of issues and variables to be included in the indicator reflects different judgments and interests (Mason 2013).

Various indicators were developed at different scales for global or national assessment and with different thematic focus, but all of them were criticized for being biased concerning certain aspects, not well-founded with data, or oversimplifying complex water-society interrelations (GWP 2012; Mason 2013; Zeitoun et al. 2013; Zeitoun et al. 2016).

ADB has attempted to cover the different dimensions of water security and also evaluate the performance of all Asian countries through a set of comprehensive indicators. Two consecutive reports of the *Asian Water Development Outlook* (AWDO 2013 and 2016) have adopted the water security definition of Grey and Sadoff mentioned above and developed the following "vision" of water security: "Societies can enjoy water security when they successfully manage their water resources and services to 1. satisfy household water and sanitation needs in all communities; 2. support productive economies in agriculture, industry, and energy; 3. develop vibrant, livable cities and towns; 4. restore healthy rivers and ecosystems; and 5. build resilient communities that can adapt to change" (ADB 2016: 15). These five aspects translate into the five dimensions of the AWDO framework: household water security, economic water security, urban water security, environmental water security, and resilience to water-related disasters.

The AWDO framework may be criticized for partial overlap of the dimensions and absence of more representative indicators as will be reviewed in the discussion section. Still, AWDO is one of the few comprehensive platforms that has repeatedly assessed water security in a quantitative manner for the entire Asian region—and for this reason has been adopted in the current study. The AWDO reports in 2013 and 2016 have provided a solid documentation of the performance of all Asian countries along the five selected dimensions through statistical techniques and ranking assessments.

Although the Central Asian countries share a common Soviet past (except Afghanistan), they are performing rather differently according to the latest AWDO assessment (2016). Kazakhstan ranks in the top 10 of 47 countries; Turkmenistan, the Kyrgyz Republic, and Uzbekistan occupy the 21st, 24th, and 29th rank, respectively; while Tajikistan was poorly ranked in 32nd position. Afghanistan received the lowest rank (47th) of all countries assessed because of its massive infrastructure problems arising from the ongoing conflicts.

The difference between Kazakhstan and the other Central Asian countries can be partly attributed to the oil and gas industry boom in Kazakhstan after the Soviet period, which accelerated economic growth including investments, also benefiting water infrastructure. According to the AWDO assessment, Central Asia's performance is also strongly affected by water governance, inefficient resource policies, and moreover strong dependence on transboundary water resources that affect regional performance (see also Araral and Yu 2013).

Also, the notion of water security can be interpreted differently in the water-producing uplands of Afghanistan, Tajikistan, and the Kyrgyz Republic, and in the water-consuming lowlands of Uzbekistan, Turkmenistan, and Kazakhstan. More than 80% of water in Central Asia originates in the mountains of the Kyrgyz Republic, Tajikistan, and Afghanistan, but more than 80% is consumed in the lowlands of Uzbekistan, Turkmenistan, and Kazakhstan.

The uneven water allocation is also attributed to the climatic conditions, which highly affect the hydrological balance in the region. All countries are located at the core of the Eurasian landmass and blocked off by mountain ranges (except for the north of Kazakhstan). This prevents or hinders the inflow of humid air from the south, thus creating the conditions for an arid to semiarid continental climate (Zomer, Wang, and Xu 2015).

The distribution of precipitation is determined to a large extent by the major topographical features of the region: lowlands and basins, such as the Kazakh steppe and the Aral basin in the north, receive much less precipitation in comparison to the highly mountainous ranges of the Pamirs, the Hindukush, and of the Tien Shan in Tajikistan, the Kyrgyz Republic, and Afghanistan.

The Pamir region includes summits over 7,000 meters above sea level and lower mountains with an average elevation of 4,000–5,000 meters. Elevations in the Tien Shan are lower with its subranges reaching 3,000–4,000 meters. The precipitation in the mountains can be quite high with average annual values of more than 1,800 millimeters in contrast to the annual average precipitation in lowlands not exceeding 150 millimeters (Xenarios et al. 2019).

Precipitation in the mountains feeds not only the headwaters of the major rivers of Central Asia, but also extensive glaciers and snowfields, which in turn serve as water reservoirs for irrigated agriculture in the adjacent lowlands during the summer when precipitation is scarce. Streamflow varies throughout the year with peak runoff during snow and glacier melt in summer, but also between years as a result of variations in rain and snowfall.

The mountainous parts of Central Asia are prone to water-related hazards such as flash floods, avalanches, mudslides, and glacier lake outburst floods, which pose a threat to human lives but also to human security by damaging infrastructure such as roads and bridges. Climatic conditions affecting water security and exposure to hazards are expected to change due to climate change and its effects on the hydrological cycle, especially in regions where glacier and snowmelt are important freshwater sources. According to a scenario presented by Xenarios et al. (2019), temperatures will have increased in 2020, relative to 1990, by 1.8°C in the Tien Shan and by 1.4°C in the Pamirs. Future climate warming will cause snowmelt to occur early in the spring, leading to floods, a shift of peak runoff from July to June, and reduced water availability in the late summer months. The accelerated glacier melting and retreat of glaciers constitute a major threat to water security in Central Asia, which is captured by the environmental and resilience dimensions in the AWDO framework.

16.3 Materials and Methods

The five dimensions (K 1–5) of the AWDO framework are assessed against the water security studies traced in Central Asia. In particular, we conduct a Boolean search by initially querying the phrase “water security Central Asia” in a set of 11 databases that cover nearly the majority of peer-reviewed studies worldwide on water security in Central Asia as presented in Appendix 16. The search for the phrase is conducted throughout the entire text, while we narrow down the study focus to peer-reviewed journals since 1992. The reasoning behind the research filter on peer-reviewed journals is the partial overlap that we have come across in working reports and books from the same authors that appeared to be further distilled in journal papers. The selection of 1992 as a baseline demarcates the evolution of water security studies after the post-Soviet era in the entire Central Asian region.

The second layer of literature review research identified the water security term matched in a country-specific context, for instance, “water security Tajikistan.” All five countries of Central Asia were considered as well as Afghanistan, which shares major transboundary basins with Tajikistan, Uzbekistan, and Turkmenistan. The findings were cross-checked with the first layer of literature research to avoid duplication.

In turn, a more context-specific research was performed on the keywords of each K-dimension. To better facilitate the research findings on the peculiarities of the Central Asian region, we modified the initial keyword provided by AWDO in each dimension. The five main categories and suggested keywords are presented in Table 16.1.

The results were then classified according to the frequency and relevance of each study on water security in Central Asia as interpreted through the above framework. The frequency rate is linearly counted and then aggregated accordingly for each dimension—that is, how many studies refer to socioeconomic water security in the region. There are some instances where a study may respond to more than one dimension by covering, for example, the economic and environmental aspects of water security. In that case, the frequency rate is equally attributed to both categories.

Table 16.1: Assessment Framework and Main Keywords

Water Security Dimension	First Layer	Second Layer	Third Layer
Household (K-1)	Water security Central Asia	Water security – Kazakhstan – Uzbekistan – Turkmenistan – Tajikistan – Kyrgyz Republic – Afghanistan	WASH Programme
			Sanitation
			Piped supply
			SDGs–6
Economic (K-2)			Agriculture
			Industry
			Energy
			WEF nexus
Urban (K-3)			Water supply
			Wastewater
			Water consumption
			Drainage
Environmental (K-4)			Ecological status
			River flow
			Hydromorphology
			Monitoring–evaluation
Resilience (K-5)			Floods
			Droughts
			Landslides
			Avalanches

SDG = Sustainable Development Goal; WASH = water, sanitation, and hygiene; WEF = water–energy–food.
Source: Authors, based on ADB (2016).

The relevance performance for each study is assessed through a Likert-scale graded from 1 (min) to 5 (max). The overall relevance for each dimension (K-1 to K-5) is measured through the aggregated mean value of the individual studies. In case an individual study covers more than one dimension, the relevance scoring is attributed as per the objectives and content of each case. The overall significance of each dimension is measured by multiplying the frequency rate with the corresponding relevance scoring—for instance, K-5 = 5 observations × 3 mean relevance = 15.

Further, we attempt to explore the potential relationship between the countries represented by authors' organizations with particular water security dimensions. We also consider the type of organization (research institute, university, etc.) as a potential driver that affects the preference or aversion toward some water security dimensions. There are, for instance, specific departments in universities and established research institutes based in the United States (US) and Europe with considerable interest in the geopolitics of Central Asia.

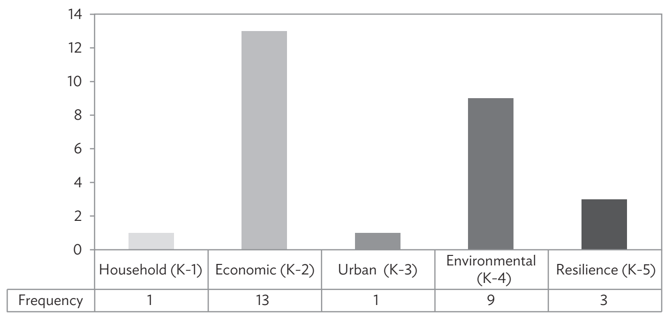
We also explore the probability that the authors' origin may have driven the research toward specific water security dimensions such as economics or urban supply. There are some cases where one or a group of scholars from Central Asia are situated in the US and Europe and show high interest in particular dimensions in specific regions (for instance, climate change and natural hazards in mountainous Central Asia). We assess the origin of the three first authors in each study as we consider them to have more influence on the development of the research output.

We employ a multinomial logit regression to explore if the country of origin of the organization, the author's origin, and the type of institute can be considered potential drivers for the assessment of the five AWDO dimensions. The multinomial logit model is part of the wider family of generalized models where probabilistic relations between dependent and independent variable are explored (Garson 2010). The regression is composed of a categorical dependent variable, which in our case are each of the five AWDO dimensions, and categorical factors or continuous covariates. In this study, we employed three categorical predictors (country, author origin, organization type). It should be mentioned that the model adopted one category of the dependent variable as a reference base for the regression analysis. In our case, the last dimension (K-5, resilience) was taken as the reference category.

16.4 Results

The initial findings of the review have covered the first and second layers (water security in Central Asia and per country) by presenting a high inclination toward the economic interpretation of water security as presented in Figure 16.1.

Figure 16.1: Frequency of Asian Water Development Outlook Dimensions in Reviewed Studies



Source: Authors.

In particular, the economic dimensions of water security are directly reflected in a number of studies with the main focus on the agriculture sector and water supply on the national and regional context (Rudenko et al. 2013; Wegerich 2011; Wegerich et al. 2015). The competing interests between agricultural water use downstream and hydropower production upstream as a means for economic development are also delineated (Guillaume et al. 2015; Jalilov, Amer, and Ward 2013; Stucki and Sojamo 2012). The contribution of water governance in economic security and agriculture is emphasized in a national context (Klümper, Herzfeld, and Theesfeld 2017).

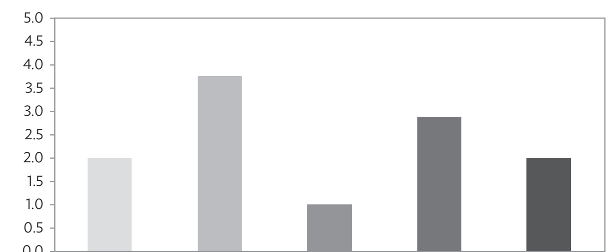
Various studies also focus on the institutional and legislative aspects by depicting the socioeconomic perspectives of water security (Abdolvand et al. 2015; Froebrich and Wegerich 2007; Himes 2017; Zakhirova 2013; Ziganshina 2011). The effects of transboundary collaboration on the economic prosperity of neighboring countries are assessed, for instance, in the case of Kazakhstan and the People's Republic of China (Stewart 2014). Transboundary complexities and conflicting interests between Central Asian countries and major external actors such as the Russian Federation and the People's Republic of China are also elaborated (Chan 2010).

Nearly half of the studies target the environmental implications of the economic dimensions by underscoring the hydromorphological impacts in the Syr Darya and Amu Darya basins from existing and new hydropower and agricultural projects. Also, the intensive water use and overconsumption practices are manifested in agriculture-related papers that also highlight the high dependency on transboundary sources (Rudenko et al. 2013). More broadly, the interdependence between upstream and downstream countries concerning access to a sufficient volume of water to fulfill agricultural and energy needs is mentioned, while potential scenarios for equable allocation are suggested (Guillaume et al. 2015; Jalilov, Amer, and Ward 2013).

More emphasis is given to the role of small lakes for recharging groundwater sources, preserving aquatic species, and providing freshwater for sustainable agricultural use (Conrad, Kaiser, and Lamers 2016). The resilient profile of water security (K-5) is sharpened by stressing the role of ecosystem goods and services in flood reduction and erosion control. Attention is also given to the role of freshwater systems for the mitigation of natural risks and hazards, mainly in studies on water–energy–food and water governance (Klümper, Herzfeld, and Theesfeld 2017). Water security on a household level (K-1) receives the least attention, whereas there are very few studies on the urban perspective (K-3) of water security in Central Asia.

The relevance of each study is presented in Figure 16.2 by confirming the prevalence of the economic dimension (K-2). The

Figure 16.2: Relevance of Asian Water Development Outlook Dimensions in Reviewed Studies
(scale 1–5)



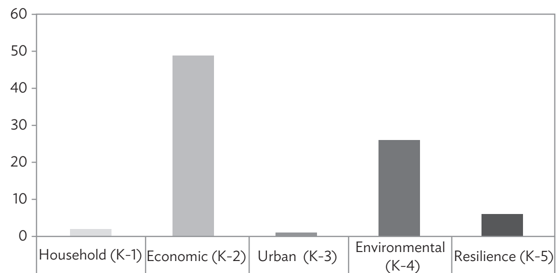
	Household (K-1)	Economic (K-2)	Urban (K-3)	Environmental (K-4)	Resilience (K-5)
Relevance Rates	2.00	3.75	1.00	2.89	2.00

Source: Authors.

importance attributed to household (K-1) and urban (K-2) dimensions, though rarely found in the studies, is boldly stated. Similarly, in the resilience dimension (K-5), the substantial role of freshwater systems for mitigating natural hazards is emphatically stressed, though only in a few studies.

The overall significance of each dimension is exhibited in Figure 16.3 where the frequency and relevance indices are aggregated. The absolute dominance of the economic dimension over all other dimensions contrasts with only some importance attributed to the environmental component.

Figure 16.3: Significance of Each Asian Water Development Outlook Dimension in Reviewed Studies



	Household (K-1)	Economic (K-2)	Urban (K-3)	Environmental (K-4)	Resilience (K-5)
Relevance*Frequency	2.00	48.75	1.00	26.00	6.00

Source: Authors.

We further distinguish between the countries in which the author's organization is based, the author's origin, and the type of each organization as shown in Table 16.2.

The representation of the research institutes in terms of country, the author's origin, and the organization types are described in Figure 16.4. The organizations based in the United States appear to have produced more studies (21.4%), followed closely by Germany (20.23%), Kazakhstan (14.2%), and the United Kingdom (10.7%).

Interestingly, in the case of the author's origin, authors originating from Germany seem to be the most prevalent (27.3%) sample, strongly outpacing those from the US (9.5%). This means that German-originated authors have published studies with organizations situated outside Germany, while much literature produced in the US was published

Table 16.2: Classification of Countries Represented, Origin of Authors, and Organization Types

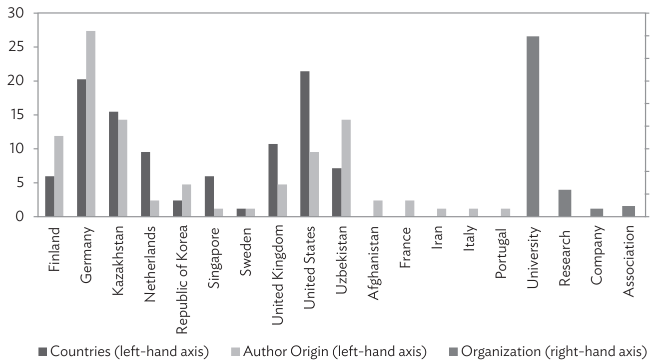
Countries Represented	Finland Germany Kazakhstan Netherlands Republic of Korea Singapore Sweden United Kingdom United States Uzbekistan Finland
Origin of Authors	Finland Germany Kazakhstan Netherlands Republic of Korea Singapore Sweden United Kingdom United States Uzbekistan Afghanistan France Iran
Organization Types	University Research institute Company, consultancy Association, organization, network

Source: Authors.

by authors of different origin. The second position is equally shared between authors of Kazakh (14.2%) and Uzbek (14.2%) origin. Authors of Uzbek origin seem to be also hosted in organizations outside their country as the representation of national (Uzbek) institutes is relatively low (7.1%). Universities appear to be predominant (79.7%) in the research output on Central Asia and water security studies, ahead of all the other categories.

It should be mentioned that to distinguish between organization types was not simple since quite often a research institute could be identified with a consultancy firm since they undertake similar activities. To overcome this hurdle, the differentiation was based on the main activities of each organization, keeping in mind that there will be overlaps.

Figure 16.4: Country Represented, Author Origin, and Organization Type



Source: Authors.

The multinomial logit model shows that only in some cases does the country representation variable have statistical significance as indicated in Table 16.3. Meanwhile, the author's origin and organization type were statistically nonsignificant ($p > 0.05$). In particular, German-based institutes seem to favor the household (K-1), urban (K-3), and economic (K-2) dimensions, while the institutes based in Finland prioritized the environmental (K-4) and economic (K-2) dimensions. Studies based in Kazakhstan and likewise the Republic of Korea and the United Kingdom do not appear to favor the economic notion of water security, as opposed to Singapore- and Netherlands-based studies, which preferred that (K-3) dimension.

Table 16.3: Logit Regression Results on Country, Author Origin, and Organization Type

Variables	Estimate	Standard Error	Lower CL 95.0%	Upper CL 95.0%	P Value
Household (K-1)	–3.3674	1.80	–7	0.2	0.061775
Germany	20.2518	1.78	17	23.7	0.000000
Economic (K-2)	12.2805	1.24	10	14.7	0.000000
Germany	11.7618	2.83	6	17.3	0.000032
Finland	6.8010	0.75	5	8.3	0.000000

continued on next page

Table 16.3 *continued*

Variables	Estimate	Standard Error	Lower CL 95.0%	Upper CL 95.0%	P Value
Kazakhstan	−13.1968	1.50	−16	−10.3	0.000000
Netherlands	6.2458	0.98	4	8.2	0.000000
Republic of Korea	−13.0735	4.34	−22	−4.6	0.002613
Singapore	6.4159	1.06	4	8.5	0.000000
United Kingdom	−10.8942	0.89	−13	−9.2	0.000000
Urban (K-3)	−0.0309	1.40	−3	2.7	0.982341
Germany	16.9152	1.37	14	19.6	0.000000
Netherlands	18.1518	1.24	16	20.6	0.000000
Environmental (K-4)	12.2473	1.12	10	14.4	0.000000
Finland	11.3896	2.62	6	16.5	0.000014
Kazakhstan	−12.0649	1.27	−15	−9.6	0.000000

CL = confidence interval.

Note: P value refers to the statistical level of significance (0.05).

Source: Authors.

16.5 Discussion

The study findings have shown a clear prevalence of the economic (K-3) dimension over all other interpretations of water security in Central Asia. The distinctively lower but yet noticeable environmental (K-2) dimension is also favored by predominantly economic studies that attempt to ascribe the quantitative and to lesser extent qualitative impacts to freshwater systems due to over-abstraction and polluting activities. Still, the environment is mostly perceived as a means to an end, or otherwise as a controlling factor to improve water supply and economic welfare in the region.

It is acknowledged that it is excessively demanding for a study to equally cover all the five dimensions of the suggested water security framework. Other similar frameworks have set fewer core dimensions such as governance and hydrology (Klümper, Herzfeld, and Theesfeld 2017; Araral and Wang 2013) or livelihoods, economic development, and ecosystems (GIZ 2017). It is noted, however, that the aim of the current study was not to assess the fulfillment of each study on all dimensions, but rather to appraise the potential prevalence of some security dimensions over others.

The distinction that the AWDO framework makes between the five dimensions may a priori bias the prevalence of some security aspects over others. For instance, the separation of the household (K-1) and urban (K-3) dimensions can further disperse the already few studies commencing on the drinking and sanitation facets of water security. Also, the environmental (K-4) and resilience (K-5) dimensions may overlap when projecting the climate change effects on freshwater systems in Central Asia. It is nevertheless noticed that even if merging the household and urban as well as environmental resilience dimensions, the results would be relatively poor compared to the economic water security dimension.

The frequency rating and the relevance scoring are based on the authors' judgments and can therefore show subjectivity and inherent biases. Moreover, the calculations are oversimplified to properly illustrate the major features of water security in Central Asia. The authors have considerable experience on water security issues in Central Asia that allows for a judgment that is as balanced as possible. The simplified assessment serves as an initial evaluation of water security studies in the region that may be used as a baseline for further studies.

The relatively limited sampling of country representation as well as the author's origin and organization type may have biased the findings. However, we have explored all the relevant databases on the first (regional) and second (country-specific) layers of water security interpretation by identifying all the potential studies. The assessment of the third layer (keynote words) is currently ongoing and is anticipated to mitigate potential biases by enlarging the literature sample.

16.6 Concluding Remarks

The current study has made a preliminary assessment of the interpretation of water security in Central Asia including Afghanistan through a literature review of published peer-reviewed sources from the beginning of the independence period until today. The absolute prevalence of the socioeconomic dimension over all other components gives a strong signal concerning the current trends of interpreting water security in the region.

The reason for this uneven distribution of water security dimensions may be due to the dire need of all Central Asian countries after independence to increase economic welfare through the exploitation of natural resources. The Soviet-dictated technocentric perception of water security through engineering interventions in the hydropower and agriculture sectors seems to have been outpaced by the perception of water resources as natural capital for economic development. These findings align with a recent study mentioning that, in the last 25 years of the post-Soviet period, looking at water issues has transformed from a technical perspective to a sociopolitical and economic approach (Xenarios et al. 2018). The environmental and natural dimensions of water resources have been downgraded, whereas urban supply and wastewater treatment have only recently been accorded some importance in Central Asia.

New institutional schemes have been established since 1991 to elaborate the water security dimensions in Central Asia for the joint allocation of common water resources. Organizations such as the Interstate Commission for Water Coordination, the Interstate Council for the Aral Sea Basin, and the International Fund to Save the Aral Sea were set up to face water security challenges among the Central Asian states. The regional organizations pay much attention to reinforcing economic growth through the maintenance of the current infrastructure and balancing agricultural (downstream) and hydropower (upstream) demands. The environmental and resilience factors have been consolidated only recently as the main parameters of climate change scenarios and are widely understood as potential threats to economic prosperity. Some institutes based mainly in the US and Europe are keen on particular dimensions of water security as indicated by the regression analysis.

The research outcomes are aligned with the current water policy dialogue between all states of Central Asia where the economic concept of water security is prevailing (Xenarios et al. 2018). The study findings suggest that socioeconomic parameters overbalance all other interpretations, which may have consequences for the interpretation of water security in the future.

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Appendix 16: Databases of Peer-reviewed Studies on Water Security in Central Asia

1. **MEDLINE Complete:** This provides authoritative medical information on medicine, nursing, dentistry, veterinary medicine, the health-care system, preclinical sciences, and much more. MEDLINE Complete uses MeSH (Medical Subject Headings) indexing with tree, tree hierarchy, subheadings, and explosion capabilities to search citations from over 5,400 current biomedical journals. It is also the world's most comprehensive source of full text for medical journals, providing full text for over 1,800 journals indexed in MEDLINE. Of those, more than 1,700 have cover-to-cover indexing in MEDLINE, and of those, over 900 are not found with full text in any version of *Academic Search, Health Source, or Biomedical Reference Collection*. This wide-ranging file contains full text for many of the most used journals in the MEDLINE index—with no embargo.

With coverage dating back to 1857 and full text back to 1865, MEDLINE Complete is the definitive research tool for medical literature.

2. **Academic Search Premier:** This multidisciplinary database provides full text for more than 4,600 journals, including full text for nearly 3,900 peer-reviewed titles. PDF backfiles to 1975 or further are available for well over 100 journals, and searchable cited references are provided for more than 1,000 titles.
3. **OpenDissertations:** This is an open-access database built to assist researchers in locating both historic and contemporary dissertations and theses. Created with the generous support of the H.W. Wilson Foundation and the Congregational Library & Archives in Boston, it incorporates EBSCO's previously released American Doctoral Dissertations, and features additional dissertation metadata contributed by select colleges and universities from around the world. Providing researchers with citations to graduate research across a span of time, from the early 20th century to the present, this database will continue to grow through regular updates and new partnerships with graduate degree-granting institutions.
4. **Business Source Complete:** This is the world's definitive scholarly business database, providing the leading collection of bibliographic and full-text content. As part of the comprehensive coverage offered by this database, indexing and abstracts for the most important scholarly business journals back as far as 1886 are included. In addition, searchable cited references are provided for more than 1,300 journals.
5. **Communication & Mass Media Complete (CMMC):** This provides the most robust, quality research solution in areas related to communication and mass media. CMMC incorporates the content of *CommSearch* (formerly produced by the National Communication Association) and *Mass Media Articles Index* (formerly produced by Penn State), along with numerous other journals in communication, mass media, and other closely related fields of study to create a research and reference resource of unprecedented scope and depth encompassing the breadth of the communication discipline. CMMC offers cover-to-cover ("core") indexing and abstracts for more than 570 journals, and selected ("priority") coverage of nearly 200 more, for a combined coverage of more than 770 titles. Furthermore, this database includes full text for over 450 journals.
6. **EconLit:** This is the American Economic Association's electronic database, the world's foremost source of references

to economic literature. The database contains more than 1.1 million records from 1886 to present. EconLit covers virtually every area related to economics.

7. **GreenFILE:** This offers well-researched information covering all aspects of human impact to the environment. Its collection of scholarly, government, and general interest titles includes content on global warming, green building, pollution, sustainable agriculture, renewable energy, recycling, and more. The database provides indexing and abstracts for more than 384,000 records, as well as open-access full text for more than 4,700 records.
8. **Library, Information Science & Technology Abstracts:** This indexes more than 560 core journals, nearly 50 priority journals, and nearly 125 selective journals, plus books, research reports, and proceedings. Subject coverage includes librarianship, classification, cataloging, bibliometrics, online information retrieval, information management, and more. Coverage in the database extends back as far as the mid-1960s.
9. **MasterFILE Premier:** Designed specifically for public libraries, this multidisciplinary database provides full text for nearly 1,700 periodicals with full-text information dating as far back as 1975. Covering virtually every subject area of general interest, the database also contains full text for nearly 500 reference books and over 164,400 primary source documents, as well as an image collection of over 592,000 photos, maps, and flags. This database is updated daily via EBSCO*host*.
10. **SocINDEX with Full Text:** This is the world's most comprehensive and highest quality sociology research database. The database features more than 2.1 million records with subject headings from a 20,000+ term sociological thesaurus designed by subject experts and expert lexicographers. SocINDEX with Full Text contains full text for more than 860 journals dating back to 1908. This database also includes full text for more than 830 books and monographs, and full text for over 16,800 conference papers.
11. **Education Resources Information Center (ERIC):** This provides access to education literature and research. The database provides access to information from journals included in the *Current Index of Journals in Education and Resources in Education Index*. Content includes journal articles, research reports, curriculum and teaching guides, conference papers, dissertations and theses, and books dating back to 1966.

PART IV
Conclusion

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Policy and the Role of the Asia–Pacific Water Forum and International Institutions Focused on the Sustainable Development Goals

Ravi Narayanan

While the Sustainable Development Goals outline the scope of the problems of water and sanitation security and lay down ambitious objectives, the scale of the effort required to attain these goals in a region as large and diverse as Asia and the Pacific is formidable. While formidable does not mean that the targets cannot be met, it does mean that a detailed understanding of the context and ingenuity and persistence will be required.

The case studies in the book cover the major parts of the Asia and Pacific region and detail the ways in which challenges in reaching water and sanitation security under different circumstances have been overcome across the region. This is buttressed by economic analysis so that the benefits of water and sanitation security and its externalities are unambiguous and compelling. Added to this are examples of innovative ways to attain the necessary levels of finance.

What is puzzling is that, despite the obvious, attention to water and sanitation security has not reached the required levels for decisive action to be unleashed. To understand why, we need to appreciate the drivers of change, perhaps from a historical perspective. The three often cited as key to general growth and development are the interrelated factors of (i) governance (related to the impact that institutions and systems have on policies, procedures, and resources); (ii) technology (acting as an accelerator and multiplier); and (iii) capacity (which enables or constrains the application of policies, procedures, or technical processes)—all within the envelope of resources, both human and financial.

Each of the three drivers is optimized in different circumstances in different ways and requires a discrete set of enabling impulses to provide the impetus to make progress. Governance, which is often cited as a key driver of progress, is complex and depends very much on the political economy of each country. The nature and architecture of institutions are often governed by each country's traditions and customary practice. The engine to drive movement and provide momentum is political will. In the Asia and Pacific region, this can emanate from top leadership, visionary and inspired, or from the forces of irresistible public demand.

Ideally, a combination of the top–down and bottom–up approaches can bring about the best results. The way in which this combination can be facilitated depends in turn on other factors. One of these is communication. In a world where there is no shortage of the means or the volume of communication, the challenge is to deliver a message about the dangers of water and sanitation insecurity—one that is compelling enough to stand out among all the others that are relentlessly promoted. This is easier said than done. The traditional method is to present a case study, more often than not of success, without an analysis of the context and the impelling and impeding factors. This is an area where the case studies in this book can set an example.

This brings us to the next factor, which is understanding the pathways to progress and scale, requiring us not only to delve deeper into the causes of events, why they happen or not, but also crucially to appreciate traditional and nontraditional ways of delivering messages and the methods by which these can be translated to action that leads to sustainable change at a large scale. In the Asia and Pacific region, with its size, variety, and diversity, these methods can vary by country from those with relatively homogeneous communities to those with diverse geophysical features and water endowments but also differences in language, ethnicity, religion, cultural traditions, and political and constitutional arrangements that make the task of building consensus and commitment to common objectives both delicate and time-consuming.

Technology has always been known to lead to breakthroughs and changes. In terms of water, developments in water treatment, reuse, and recycling have transformed countries' status from water insecure to water secure, and can do the same for others. Recent developments in satellite technology have helped in tracking both surface flows and mapping groundwater aquifers. These can help to accelerate beneficial changes—provided yet another factor comes into play.

The other factor is capacity development. While often confused with training, in the context of water and sanitation security and general development, capacity development means much more. Familiarity with technology and the ability to appreciate the value of sophisticated and complex engineering systems are all essential, but so is the ability for institutions to develop policies and values that promote the common good and the ability to plan, execute, maintain, and evaluate projects and programs. It is not common to associate leadership with capacity development, but it is an essential link. Leadership need not be vested in one person. The wider the spread of leadership attributes—those of knowledge, a holistic understanding of the water sector, and the ability to keep up with technical and social changes, to cope with trade-offs, and to develop collective action—among legislators, service providers, regulators, the judiciary, academia, and opinion formers of all types, the sounder and more sustainable will be the attainment of water and sanitation security.

One factor that is not discussed widely and can be seen as too sensitive for open public discussion, but which nevertheless has an impact on development processes in general, is culture. While it should be handled with care, investigators and researchers working on issues material to the theory and practice of development need, at the very least, to be aware of the cultural aspects of development and their effects on practice.

The interlinked chain of factors, actions, and objectives is complex, and reaching the Sustainable Development Goals is unlikely to happen by the efforts of a single entity in many places. It requires the combined and harmonized efforts of many people, organizations, and institutions. This brings us to Sustainable Development Goal 17, which is about strengthening partnerships. Surprisingly this goal does not receive the level of attention as it perhaps should. One reason may be the difficulty in building trust and the tendency to be competitive rather than collaborative. Several organizations in Asia and the Pacific have tried to address this issue by dedicating their work to developing partnerships and bringing together organizations with experiences to share in different parts of the development mosaic, policy initiatives technology, capacity building, innovative financing, and innovative communication methods and techniques. These surely are efforts worthy of support and emulation.

An example of one such partnership to form the basis for sharing information, knowledge, and experience leading to action is the Asia–Pacific Water Forum. Started in 2006 after the fourth World Water Forum, with exemplary commitment by the Asian Development Bank and the Japan Water Forum and support of their dedicated officers, it was designed as an open platform to bring together the formidable experience of developing water security in the Asia and Pacific region.

While available, this wealth of experience had not been readily shared previously. Since its inception, the Asia–Pacific Water Forum has helped develop impetus by focusing on key initiatives. Two that are by now well established as regular features are the Asia-Pacific Water Summit, which ensures continuing political commitment to the cause of water security, and the *Asian Water Development Outlook* report, which assesses and tracks progress in the achievement of water security in every country in the region. None of this would have been possible without the willingness and ability of governments and organizations, big and small, working across the region with trust and in partnership, a spirit essential to the realization of the Sustainable Development Goals.

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Conclusions and the Way Forward

Eduardo Araral, Naoyuki Yoshino, and KE Seetha Ram

Several conclusions can be drawn from this volume. First, developing countries in Asia, South Asia in particular, face an enormous challenge in providing water and sanitation services. These challenges are aggravated by rapid urbanization, weak and dysfunctional institutions, lack of political will, climate change, water pollution and scarcity, and the problem of financing given the risks and low returns to investments, especially in sanitation.

Second, there are significant benefits to society if the problems of water supply and sanitation can be resolved. Countries that have addressed their water and sanitation problems have seen a significant drop in public health-care costs stemming from waterborne diseases such as diarrhea, cholera, typhoid, dysentery, and hepatitis. Cities and towns that can provide water and sanitation infrastructure have seen significant improvements in local economic development as well as increases in property values. With sanitation, groundwater would be preserved for future use while helping to recharge aquifers. Other economic benefits include the reuse of treated water for agriculture and/or industrial purposes, and benefits in terms of waste to energy.

Third, despite these significant societal benefits, governments have little incentive to invest in water and sanitation infrastructure, in large part due to limited budgets and lack of political will. Political incentives are often misaligned. Politicians tend to promise free water and sanitation services, and, as a result, water and sanitation utilities do not have enough funds to pay for the expansion, operation, maintenance, and sustaining the services. The private sector also has little incentive to invest, especially in sanitation, given the high risks, high capital costs, and low financial rewards. Public–private partnerships in the water and sanitation sector have mixed results. Even one of the best performing partnership in water, Manila Water, has failed to address the problem of sanitation in Metro Manila in the Philippines.

Fourth, some countries have nevertheless managed to tackle the enormous challenges in water and sanitation. The countries and cities documented in this volume that have done so—Japan, the Republic of Korea, Malaysia, and the Philippines—are either rich or middle-income countries. This highlights that investments in water and sanitation tend to be correlated with a country's level of income.

Fifth, new and innovative ways fortunately exist to solve the problem of sustainable financing for water and sanitation services that do not depend on a country's income level, and that provide incentives to the private sector and governments to invest in infrastructure. Such innovative methods, demonstrated in Dumaguete City in the Philippines, are based on the idea that water and sanitation infrastructure generate positive spillover effects, which can be captured and returned to the investor to increase the rate of return—and hence the incentive to invest. For instance, water and sanitation infrastructure leads to higher property values, meaning higher tax collection that can then be reinvested in other infrastructure that can then generate more societal benefits and higher tax collection, thereby creating a virtuous cycle.

The fecal sludge management project in Dumaguete City, for example, yielded benefits equivalent to 6.3 times the initial cost of the capital investment. The Dumaguete project is a concrete proof of concept solution of capturing the spillover benefits as an incentive for governments and the private sector to invest in sanitation.

Moving forward, the first challenge is for national and local politicians and technocrats to understand how this innovative mechanism for infrastructure financing works. Second, governments and donors need to demonstrate the proof of concept in their respective countries. Political leadership is central to make this happen. Third, technocrats should devise tax mechanisms to capture these spillover benefits as well as expenditure mechanisms to reinvest these funds to fund capital and operation and maintenance investments in the future.

Development partners have an important role to play in providing technical assistance in setting up these demonstration projects in developing countries, documenting lessons learned, developing local capabilities and expertise for possible roll-out of the concept on a nationwide basis, and advisory assistance in devising the tax and expenditure mechanisms.

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Water Insecurity and Sanitation in Asia

As Asia rapidly urbanizes, providing water and sanitation services has become problematic. Most developing country governments in the region cannot deliver the required services themselves, and the private sector is reluctant to invest due to the risks and low returns, especially for sanitation. Public–private partnerships in water supply and sanitation have had mixed results, making sustainable sanitation a particularly challenging problem.

Fortunately, there are new and innovative ways to solve the problem of sustainable financing for water and sanitation services. This book brings together a collection of studies that discuss the recent developments in the water and sanitation sector in Asia and, most importantly, identify their spillover effects. This first attempt of its kind aims to give budget-constrained policy makers the incentive to introduce these approaches for the sustainable financing of infrastructure and, in particular, water and sanitation.

"I offer my congratulations to the Asian Development Bank Institute, the Lee Kuan Yew School of Public Policy, and all authors on their excellent volume comprising 18 chapters that examine various innovations in the water and sanitation sector in Asia.

The studies illustrate how water and sanitation infrastructure can generate positive spillover effects, such as reductions in morbidity from waterborne diseases and the appreciation of urban property values.

I sincerely hope that policy makers in Asia will consider the innovative approaches discussed in this volume to accelerate progress toward water security in the region."

Yoshiro Mori
Former Prime Minister of Japan
President, Asia-Pacific Water Forum

About the Asian Development Bank Institute

ADB Institute, located in Tokyo, is the think tank of the Asian Development Bank, an international financial institution. ADBI aims to be an innovative center of excellence for the creation of rigorous, evidence-based knowledge that can be implemented as new actionable policies by developing and emerging economies, so as to contribute to achieving a prosperous, inclusive, resilient, and sustainable Asia and the Pacific.

About the Lee Kuan Yew School of Public Policy

The Lee Kuan Yew School of Public Policy, part of the National University of Singapore, is one of the top public policy schools in Asia. The Institute of Water Policy is one of four research centers at the school. Its mission is to help improve water policy and governance in Asia through research, training, thought leadership, and consulting.

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