Sustainable Development Goals
Policy Brief Series No.9

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A Case Study of Sewage & Wastewater Policy, Treatment Systems in Korea, and How This Experience Can Be Applied to Developing Countries

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Acknowledgements

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Acronyms

BOD	Biochemical Oxygen Demand
BTL	Build-Transfer-Lease
BTO	Build-Transfer-Operate
CLSWP	Conventional Local Sewage Works Program
COD	Chemical Oxygen Demand
DPR	Direct Potable Reuse
DRC	Democratic Republic of Congo
IWSWP	Integrated Watershed Sewage Works Program
K-eco	Korea Environment Corporation
KOICA	Korea International Cooperation Agency
KRW	Korean Won
LDCs	Least Developed Countries
LICs	Lower Income Countries
LMICs	Lower Middle Income Countries
MICs	Middle Income Countries
MOE	Ministry of Environment
ODA	Official Development Assistance
O&M	Operations and Maintenance
PMC	Project Management and Consulting
PPM	Parts Per Million
PPP	Public-Private Partnership
SS	Suspended Solid
STPs	Sewage Treatment Plants
TMS	Tele-monitoring System
T-N	Total Nitrogen
T-P	Total Phosphorus
TU	Toxic Unit
UMICs	Upper Middle Income Countries
USPC	UNDP Seoul Policy Centre
WWTPs	Wastewater Treatment Plants

1 Introduction

South Korea (hereinafter referred to as "Korea") successfully transitioned from being an aid recipient country after the Korean War to the world's 11th largest economy.[1] Industrialization and urbanization took place at a rapid pace during this transition period; significantly increasing the population density in cities, such as Seoul and Busan. Consequently, various environmental challenges emerged including issues with sewage, waste management, wastewater[2], and air pollution. To address these challenges, clean water policies were implemented in an effort to improve health and public sanitation.

Korea's sewerage system has developed remarkably well over the last 50 years, overcoming historical hardships and difficulties including, Japanese occupation, the Korean War, and post-war recovery. With no prior Sewage Treatment Plants (STPs) in existence, the completion of the Cheonggyecheon STP in 1976 was a critical starting point for sewage and wastewater management in Korea.

The government embarked on an effort to develop Korea's sewage and wastewater management framework following the 1988 Seoul Olympics and 1991 Nakdong River contamination episodes. Four different laws were enacted between 1999 and 2002, collectively known as the 'Acts on Four Major River Basins'. These laws led to the establishment of the Watershed Management Fund, which became a turning point for local governments allowing them to actively invest in sewage and wastewater management[3].

This report will discuss the developmental history of Korea's sewage and wastewater treatment framework. Followed by a look into technologies, policies, and financing options which could potentially be applied to developing countries[4].

1. World Bank. "GDP ranking." *GDP ranking | Data*, data.worldbank.org/data-catalog/GDP-ranking-table. [Last accessed on: November 20, 2018]
2. In this report, the terms "sewage" and "wastewater" both refer to water that has been degraded by human use. However, for clarity, "wastewater" refers to a byproduct of industrial or commercial activities, whereas "sewage" refers to negatively impacted water and excludes wastewater.
3. OECD. "OECD Environmental Performance Reviews: Korea 2006." *OECD Environmental Performance Reviews*, 2006, doi:10.1787/9789264024045-en.
4. In this report, developing countries refer to both least developed countries and middle income countries.

2

Korea's Experience in Sewage and Wastewater Management

2.1. Historical background

2.1.1. Major changes in sewage and wastewater management policy and framework

Beginning of economic growth (1960s~1970s)

Korea's Five-Year Economic Development Plan, which started in 1962, became an important turning point for urbanization and industrialization. However, as a result, serious environmental pollution problems began to emerge during the 1970s. In response to Korea's water pollution challenges, the government introduced countermeasures such as restructuring the central government's sewerage organizations. Improvements were also made in local sewerage administration, the facilities (treatment plants, sewer pipes), and government budgets. As a result, Korea was able to construct its first STP, known as the Cheonggyecheon STP. The Cheonggyecheon STP had a capacity of 150 thousand m^3 per day. It could treat domestic waste generated by 1.3 million people in the vicinity (5,600 ha) by using the activated sludge process[5]. The Cheonggyecheon STP was integrated with the Jungnang STP, and was later renamed the Jungnang Sewage Treatment Center.

Table 1: Construction status of STPs in the 1970s

Sewage Treatment Plant (STP)	Construction Period	Treatment Process	Capacity (m^3/day)	Treated Population (Unit: 1,000)	Project Cost (Unit: KRW 1,000)		
					Total	Domestic Capital	Foreign Loan
Cheong-gyecheon STP	1970.6~ 1976.9	Activated sludge process	150,000	1,300	6,100,000	3,100,000	3,000,000
Jungnang STP	1975.12~ 1979.12	Activated sludge process	210,000	800	10,150,000	6,150,000	4,000,000

Ministry of Environment, 2016, *Historical Development of Korea's Sewerage System*.

5. Ministry of Environment, 2016, *Historical Development of Korea's Sewerage System*.

Figure 1: Cheonggyecheon and Jungnang STPs

Cheonggyecheon STP

Jungnang STP

Ministry of Environment, 2016, *Historical Development of Korea's Sewerage System*.

Rapid economic growth and accession to the OECD (1980s~1990s)

During the 1980s and 1990s, rapid industrialization, population growth, and urbanization resulted in untreated wastewater being discharged into public water bodies, causing a decline in water quality.

As Korea prepared to host the 1986 Asian Games and the 1988 Seoul Olympics, there was a visible need for improvements in sewerage distribution rates and the need for extensive construction of STPs. There was a particular focus on Seoul, since the two international events were being held in the city. There were insufficient STPs and flush toilets, along with an unpleasant odor from excreta that remained noticeable in Seoul. The possibility of negative media coverage generating a negative image of the city served as a driving force behind increasing the distribution rate of flush toilets. These increases not only took place in large buildings in downtown areas but also in households. The rapid expansion of flush toilets necessitated securing water for these toilets. This resulted in an increase of STP construction, which in turn led to awareness about conserving water quality.

The water quality of rivers also improved during this period through an integrated river basin management approach. Strengthened regulatory requirements to reduce pollution contributed to improvements in water quality. Furthermore, sewage and wastewater started being treated by municipal entities, public corporations (such as Korea Environment Corporation), and private companies.

Despite Korea's rapid economic growth, many water contamination incidents occurred nationally. In 1991 and 1994, two serious accidents occurred in the Nakdong River. The incidents caused the drinking water of the Busan Metropolitan Area and Gyeongsangnam Province to be contaminated by volatile organic pollutants, including phenol. Two massive fish kills occurred consecutively in the Yeongsan and Imjin Rivers[6]. Investigations found that organic sediment from Gwangju's riverbed

6. Asian Institute for Energy, Environment and Sustainability (AIEES) of Seoul National University. "The Water Shed Management Act of Korea | Environmental ..." *Environmental Performance Index*, archive.epi.yale.edu/indicators-in-practice/water-shed-management-act-korea

had leaked into the Yeongsan River due to rainfall, resulting in a massive number of fish being killed due to a lack of dissolved oxygen. In April 1995, approximately 1.8 million m^3 of untreated sewage leaked into the Geum River due to the breakdown of a floodgate installed in the sewage inlet of the Daejeon STP[7]. Similarly, other water pollution-related accidents occurred frequently during the 1990s. Leading to a rapidly growing awareness about the importance of environmental protection. The figure below provided images from these water pollution accidents.

Figure 2: Water pollution incidents that occurred during the 1990s

Rally against the Nakdong River contamination accident

Massive fish kill

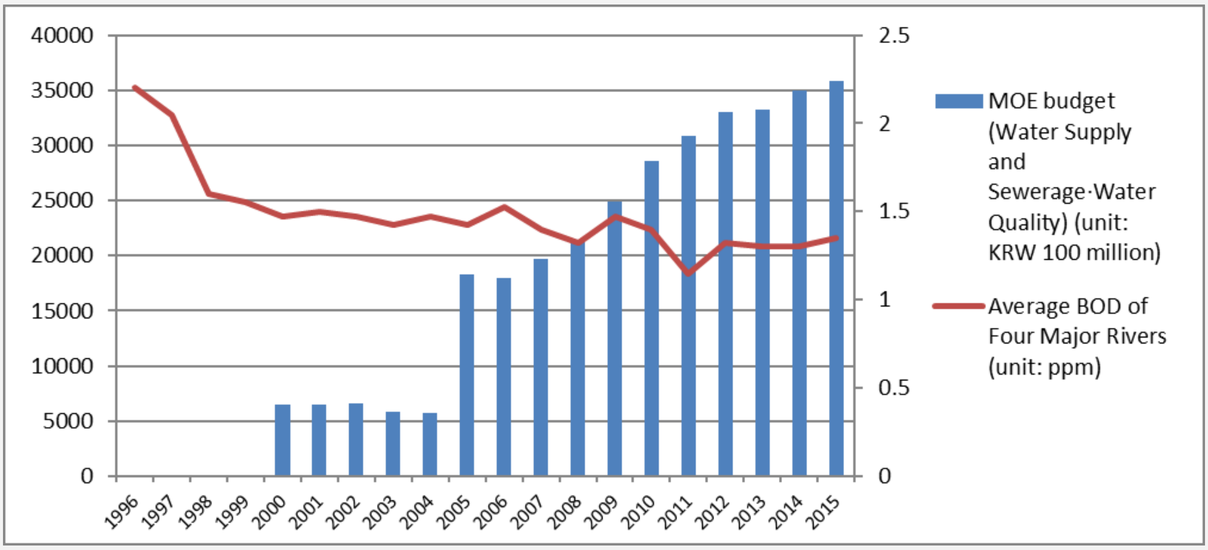
Toward a sustainable and advanced society in the new millennium (2000s~2015)

The Ministry of Environment (MOE) made improvements in its administrative organization and its sewerage services, while also implementing new sewerage policies. Following a pilot project on developing technology for removing nutrients from raw sewage, advanced STPs were built. Likewise, large-scale business projects were piloted and investments were made after the declaration of the 'First Year of Sewer Pipe Rehabilitation' by the government in 2002[8]. Moreover, waste water treatment plants (WWTP) were expanded and effluent water quality standards were strengthened.

The water quality of the Four Major Rivers[9a] has improved since the mid-1990s, due to the expansion and improvement of environmental facilities like STPs which were constructed in accordance with the government's comprehensive water management measures as illustrated by Figure 3. The government established the 'Water Basic Plan' in 2006 and proposed to improve 97 out of the 115 mid-sized sub-basins of the Four Major Rivers into "good water" by 2015. According to Korea's water quality standards, a biochemical oxygen demand (BOD)[9b] level of 3mg/L or less is regarded as "good water[10]".

7. Ministry of Environment. 2016. *Historical Development of Korea's Sewerage System*.
8. Ibid.
9a. Four Major Rivers of Korea are: Han River, Nakdong River, Keum River, Youngsan River.
9b. BOD (mg /L or ppm): The amount of dissolved oxygen demanded by aerobic biological organisms to decompose organic matter present in a given water sample. Higher BOD levels mean lower water quality.
10. This implies that the government's goal is not to lower the BOD level to zero, but rather manage and maintain it as "good water".

Figure 3: MOE budget for water quality preservation and the average BOD of Four Major Rivers[11]



2.1.2. Distribution of sewerage systems

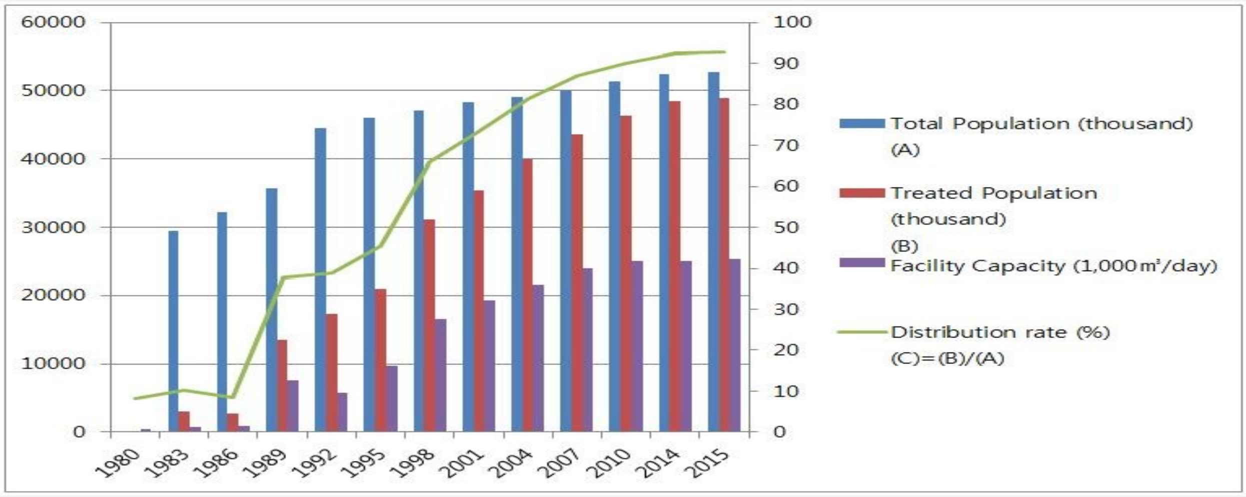
Sewerage systems Before the number of STPs began to increase, Korea's sewerage system distribution rate was very low, about 8.3 percent in 1980[12]. After going through rapid economic growth, the distribution rate exceeded 90 percent in 2010, and reached approximately 93 percent in 2015[13], placing Korea on par with various developed countries.

Sewer pipes Sewer pipes are an important factor in the sewerage system. The role of sewer pipes in a sewerage system can be compared to the role of veins in a human body. Within this analogy, STPs function as a heart. Sewage can be treated properly once sewer pipes are adequately installed and operated.

A significant problem in Korea's sewerage development is that policies related to the construction of STPs were created and implemented without sufficient attention being placed on the construction or maintenance of sewer pipes. The government made improving the quality of contaminated water and making visible achievements on improving sewerage system distribution rates a priority.

11. The unit for the MOE budget in KRW 100 million (for water supply and sewerage · water quality) is on the left Y-axis, whereas the unit for average BOD of four major rivers is on the right Y-axis
12. Ministry of Environment. *Historical Development of Korea's Sewerage System*.
13. Ministry of Environment. *2015 Sewerage Statistics*, www.me.go.kr. [Last accessed on November 20 2018.].

Figure 4: South Korea's distribution rate of sewerage systems[14]

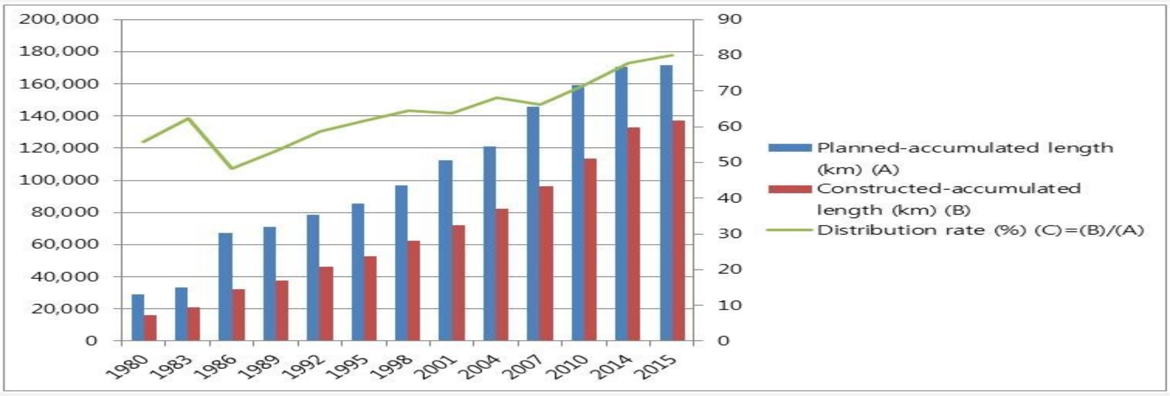


Hasudoinfo, www.hasudoinfo.or.kr

As a result, the inflow of low-concentration sewage efficiency of the STPs declined and uncollected sewage was discharged into the river. Treatable sewage could not be delivered to STPs, and thus many of them did not have enough actual sewage to treat[15].

To overcome this problem, the 'First Year of Sewer Pipe Rehabilitation' was declared in 2002, and sewer pipes that had suffered from underinvestment started to receive more funding and policy support for management and construction. In 1980, the length of sewer pipes covered 16,182 km with a distribution rate of 55.9 percent[16]. However, by 2015, the size of this network increased to 137,193 km with a distribution rate of approximately 80 percent[17]. As a result, river quality improved and the goal of operating a balanced and sound sewerage system was reached.

Figure 5: South Korea's distribution rate of sewer pipes[18]



Hasudoinfo, www.hasudoinfo.or.kr

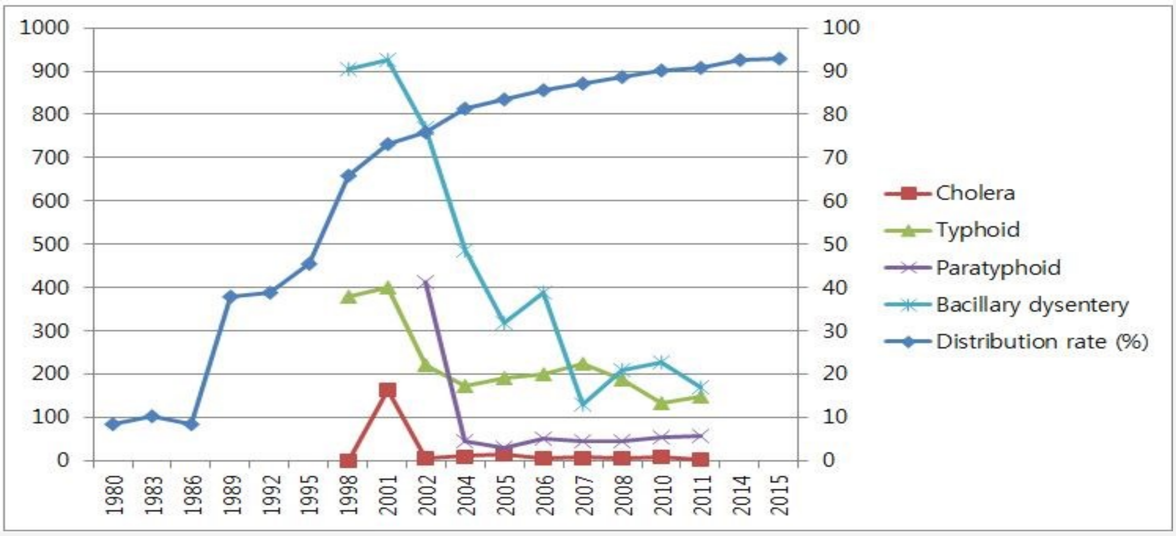
14. The unit for the total population, treated population, and facility capacity is on the left Y-axis, whereas the unit for the distribution rate (percentage) is on the right Y-axis
15. Ministry of Environment. 2011. "*Keeping Water Clean. Some Success Stories of Korean Environmental Policies.*" Ministry of Environment. *Historical Development of Korea's Sewerage System*.
16. Ibid.
17. Ministry of Environment. *2015 Sewerage Statistics.*
18. The unit for the planned-accumulated length and the constructed-accumulated length is on the left Y-axis, whereas the unit for the distribution rate (percentage) is on the right Y-axis.

2.1.3. Sewerage systems and health improvement

Sewage and wastewater are useful for farming areas in developing countries, but they can be harmful to human health and the environment when untreated or treated inadequately. For instance, soil that is irrigated by sewage or wastewater, pollutants such as heavy metals, salts, and pathogens can easily accumulate and cause land degradation. As a result of inadequate sewage treatment, inhabitants in urban and peri-urban areas are often exposed to polluted groundwater. This is dangerous as groundwater is the primary source for potable water and other water needs for millions of people living in low-income communities around the world.

Pathogenic micro-organisms populated in contaminated water can cause waterborne diseases such as cholera, dysentery, typhoid, and polio. There have been six outbreaks of cholera in Korea since the 1960s. During one such outbreak in 1969, there were 130 deaths nationwide[19]. Since then, outbreaks of typhoid fever and bacterial dysentery have greatly declined, but waterborne diseases caused by the collective use of the same water resource remain an important concern for public health[20]. Infections for example can occur through direct contact due to bathing and washing with contaminated water. They can also occur through indirect contact due to consumption, preparation, and purchase of contaminated food. Globally, 1.8 billion people still drink water from a source contaminated with excreta, putting them at risk of contracting waterborne diseases[21]. Approximately, 842,000 deaths occur each year due to unsafe drinking water, poor sanitation, and hygiene[22].

Figure 6: Waterborne disease outbreaks and the distribution rate of sewerage systems[23]



19. Lee, Byung-Kook, et al. "Future Oriented Water Environment Target and Management." 2013.
20. Ibid.
21. World Health Organization. 2017. "World Water Day 2017: Why Waste Water?"
22. Ibid.
23. The Unit for the number of waterborne disease outbreaks is on the left Y-axis, whereas the unt for the distribution rate of sewerage systems (percentage) is on the right Y-axis.

Efficient sewerage systems help enhance public hygiene and prevent water pollution by treating sewage and excreta generated by human activities. This is clearly demonstrated by the Korean case where rates of water-borne diseases decreased after the expansion of sewerage systems. In addition to cholera, prevalence of typhoid and bacillary dysentery also decreased.

Case study 1

Sanitation and diarrhea in low- and middle-income countries[24]

Effect of improvements in sanitation on diarrheal disease risk

The impact of sanitation interventions on the risk of diarrhea were analyzed with a focus on three groups, including: those using unimproved sanitation[25]; those using improved (on-site) sanitation[26]; and those living in communities with access to a sewerage system or other systems removing excreta entirely from the community. Results showed that a mean diarrheal reduction of 28 percent could be achieved by shifting from a baseline of unimproved sanitation to improved sanitation (including sewerage facilities). When sewerage connections are excluded from the analysis, the health gains are smaller but still significant, with an expected reduction in disease risk of 16 percent.

Burden of diarrheal disease from inadequate sanitation

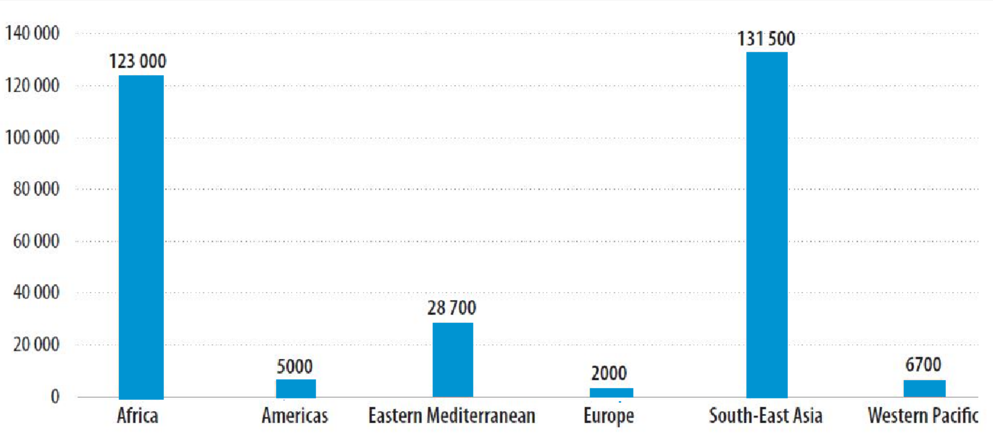
The burden of diarrheal disease was estimated through the distribution of the population using improved or unimproved sanitation facilities and the differences in the risk of diarrhea experienced by those groups. Data from 2012 shows a total of 280,000 deaths in lower-middle income countries that can be attributed to diarrheal disease caused by inadequate sanitation. The regional breakdown of these deaths is shown in Figure 7. The estimated burden of disease would have been higher if sewerage connections had been considered.

24. World Health Organization. 2014. "Preventing diarrhea through better water, sanitation, and hygiene: exposures and impacts in low– and middle-Income countries."
25. Unimproved sanitation facilities do not ensure the hygienic separation of human excreta from human contact. They include pit latrines without a slab or platform, hanging latrines, and bucket latrines. In addition, open defecation is included in unimproved sanitation, meaning human excreta disposed of in fields, ofrests, bushes, open bodies of water beaches, or other open spaces with solid waste (WHO, 2014).
26. Improved sanitation facilities are likely to ensure hygienic separation of human excreta form human contact. They include flush/pour flush to a piped sewer system, septic tank, pit latrines; ventilated improved pit (VIP_) latrine; pit latrine with slab; and composting toilet (WHO, 2014).

Policy implications

This analysis implies that the provision of improved sanitation in households significantly reduces diarrhea. Increasing access to basic sanitation at the household level is a crucial but overlooked public heath measure for the prevention of diarrhea.

Figure 7: Deaths from inadequate sanitation in LMICs by region (2012)



World Health Organization. 2014. "*Preventing diarrhoea through better water, sanitation and hygiene: exposures and impacts in low-and middle-Income countries.*"

Case study 2

Vulnerable segments of the population suffer in areas irrigated with untreated sewage and wastewater[27]

A study that examined the health implications of sewage and wastewater irrigation on children (8-12 years) in peri-urban Aleppo, Syria, revealed significantly higher prevalence rates (75 percent) of waterborne diseases, such as gastroenteritis, in the untreated wastewater-irrigated area than in the freshwater-irrigated area. Only 13 percent of children were affected by the disease in the latter. The annual health cost per child (expenses for physician fees and medicine costs) was 73 percent higher in untreated sewage and wastewater areas compared to the same age group in freshwater areas. In contrast, the prevalence rates of non-waterborne diseases, such as chickenpox, compared between freshwater and untreated sewage and wastewater-irrigated areas were insignificant. These findings suggest that children, the most vulnerable group, are at a great risk to waterborne diseases in untreated sewage and wastewater areas. This also highlights the importance of strategic policies and investments as well as the safe and productive use of sewage and wastewater policies compared to spending on healthcare.

2.2. Current policies and systems for sewage & wastewater management

2.2.1. Framework of main policies focused on sewage

Roles and responsibilities of various entities

Local governments are responsible for the construction and management of public sewerage systems while the MOE supports the budget allocation and drafts the regulatory framework. Local governments typically formulate a Framework Plan for Sewerage Maintenance and review it every five years. It is a 20-year basic plan approved by the MOE, which aims to improve public sanitation and human health by adhering to the water quality standards set by the Framework Act on Environmental Policy and the Master Plan for Nationwide Sewerage System. Existing STPs are improved by the advanced treatment process, and the efficiency of digestion tanks has also increased.

27. Qadir, M., and J. Mwachiro. 2017. *Towards a World Free of Untreated Wastewater.* UNU-INWEH Policy Brief, Issue 2. United Nations University Institute for Water, Environment and Health. Hamilton, Ontario, Canada.

Expansion of sewerage systems

Sewage treatment networks have gradually expanded to most areas in Korea with coverage reaching 92.9 percent at the end of 2015[28]. Nevertheless, there is a sewage treatment gap between urban and rural communities[29]. In 2012, the sewerage system distribution rate was 94.6 percent in urban areas but only 62.1 percent in rural localities. Sewerage systems in rural areas will be continuously expanded to address the service gap between urban and rural.

Rehabilitation of sewer pipes

Constructing and maintaining sewer pipes is an ongoing process. As of 2015, the total length of sewer pipes in Korea was 137,193 km, which corresponds to 79.9 percent of the planned length outlined in the Framework Plan for Sewerage Maintenance. While there has been progress, as noted before, an urban-rural divide remains. The sewer pipe distribution rate was 100 percent in Seoul in 2015, while it was only 60.8 percent in some rural areas in the same year[30]. Moreover, as climate change leads to an increase in intense rainfall events and subsequent risks of floods, improving the surface drainage capacity of public sewerage systems has become critical. To address this challenge, Korea is expanding its sewerage infrastructure.

Private sewage treatment

In rural areas with scattered pollution sources, it is often costly to construct public STPs. As a result, private STPs have been utilized in areas where it is cost-ineffective to construct public STPs. From 2007, it was required that private STPs exceeding a particular size have a designated specialist managing and are constructed by professional service companies[31]. As of 2015, a total of 464,875 private STPs are being operated outside of the sewage service zones[32].

Excreta treatment plants

Excreta treatment plants handle most of the waste generated from non-flush toilets and the residue from septic tanks and STPs. Since public STPs are widespread, it is often more efficient to treat excreta in connection with public STPs rather than constructing new excreta treatment plants. Wastes and residues can then be transported and treated by public STPs after primary treatment in discharging facilities. As of 2015, a total of 189 excreta treatment plants with a capacity of 39,233 m^3 per day were being operated nationwide, with approximately 77 percent of them connected to public STPs[33].

28. Ministry of Environment. *2015 Sewerage Statistics*.
29. Ministry of Environment. *ECOREA Environmental Review 2015*. eng.me.go.kr/eng/web/index.do?menuId=30
30. Ministry of Environment. *2015 Sewerage Statistics*.
31. Complete revision (9th) of the Sewerage Act on September 27, 2006 (Enforcement on September 28, 2007)
32. Ministry of Environment. *2015 Sewerage Statistics*.
33. Ibid.

2.2.2. Framework of main policies focused on wastewater

Wastewater Treatment Plants (WWTPs) in industrial complexes

WWTPs are constructed to treat large volumes of wastewater discharged from industrial complexes. From 1983 to 1991, six WWTPs were constructed with investment from the National Treasury[34]. This was expanded to a total of 81 WWTPs in industrial complexes by 2012[35]. After construction, the operating cost is covered by payments from the facilities that discharge wastewater)based on the polluter-pays principle) with assistance from the National Treasury.

Effluent standards for industrial wastewater

Effluent standards applied to individual companies aim to control pollutants from industrial sectors. The standards involve 49 parameters, including organic substances, suspended solid, and heavy metals. The characteristics of the water body, such as water quality grades, are considered in the application of the effluent standards. In 1997, effluent standards were expanded, including nitrogen and phosphorus for facilities located in Paldang Lake, Daecheong Lake, and the Nakdong River basin as a means of controlling eutrophication[36]. Such standards have been extended nationwide since 2003. In order to measure the toxic impact that unknown hazardous substances have on the ecosystem, the toxic unit (TU) was established. Since 2010, TU standard has gradually been applied to industrial facilities, STPs, and WWTPs . Table 2 shows the effluent standards of WWTPs that treat wastewater from industrial complexes.

Table 2: Effluent standards of WWTPs[37]

Category	Applied date and water quality standards									
	~2010.12.31.	2011.1.1.~ 2011.12.31.	2012.1.1.~2012.12.31.				2013.1.1.~			
			Area Ⅰ	Area Ⅱ	Area Ⅲ	Area Ⅳ	Area Ⅰ	Area Ⅱ	Area Ⅲ	Area Ⅳ
Biochemical Oxygen Demand (BOD)(mg/ℓ)	Less than 20(30)	Less than 20(30)	Less than 20(30)	Less than 20(30)	Less than 20(30)	Less than 20(30)	Less than 10(10)	Less than 10(10)	Less than 10(10)	Less than 10(10)
Chemical Oxygen Demand (COD)(mg/ℓ)	Less than 40(40)	Less than 40(40)	Less than 40(40)	Less than 40(40)	Less than 40(40)	Less than 40(40)	Less than 20(40)	Less than 20(40)	Less than 40(40)	Less than 40(40)
Suspended Solid (SS)(mg/ℓ)	Less than 20(30)	Less than 20(30)	Less than 20(30)	Less than 20(30)	Less than 20(30)	Less than 20(30)	Less than 10(10)	Less than 10(10)	Less than 10(10)	Less than 10(10)
Total Nitrogen (T-N)(mg/ℓ)	Less than 40(60)	Less than 40(60)	Less than 40(60)	Less than 40(60)	Less than 40(60)	Less than 40(60)	Less than 20(20)	Less than 20(20)	Less than 20(20)	Less than 20(20)
Total Phosphorus (T-P)(mg/ℓ)	Less than 4(8)	Less than 4(8)	Less than 0.2(0.2)	Less than 0.3(0.3)	Less than 0.5(0.5)	Less than 4(8)	Less than 0.2(0.2)	Less than 0.3(0.3)	Less than 0.5(0.5)	Less than 2(2)
Total Number of Colon Bacillus (per mℓ)	3,000	3,000	3,000	3,000	3,000	3,000	3,000(3,000)	3,000(3,000)	3,000(3,000)	3,000(3,000)
TU	-	Less than 1(1)	Less than 1(1)	Less than 1(1)	Less than 1(1)	Less than 1(1)	Less than 1(1)	Less than 1(1)	Less than 1(1)	Less than 1(1)

Ministry of Government Legislation, www.law.go.kr. Last accessed: November 26th, 2018.

34. Ministry of Environment. *ECOREA Environmental Review 2015*.
35. Ibid.
36. Eutrophication is the enrichment of a water body with nutrients, usually with an excess amount of nutrients. This induces growth of plants and algae, and may result in oxygen depletion of the water body.
37. Area Ⅰ: Areas designated and announced as drinking water protection areas, areas in which rivers flow into the Sae mangeum project area, etc. Area Ⅱ: Areas where the chemical oxygen demand (COD) or total phosphorus (T-P) value exceed or are very likely to exceed the target standard. Area Ⅲ: Mid-sized sub-basins designated in Han, Ge um, Nakdong, Youngsan, and Seomjin Rivers. Area Ⅳ: Areas excluding areas Ⅰ, Ⅱ, and Ⅲ.

Permit and reporting system required for wastewater discharging facilities

A permit or reporting system is required prior to the construction of facilities that discharge wastewater. Therefore, facilities that may significantly influence water quality must obtain a permit from the local government. For example, facilities located in Special Measures Areas[38] or those that discharge particular hazardous water pollutants (25 substances including phenol designated by law) are required to get permission before the construction takes place. The figure below shows the actual construction permit and reporting certificate.

Figure 8: Permit and reporting system for wastewater discharging facilities

폐수배출시설 설치 허가증

포 천 시 장

Construction Permit[39]

폐수배출시설설치

□ 허가증

■ 신고증명서

136-10-72423

2011 년 03 월 09 일

인 천 광 역 시 장

Reporting Certificate[40]

(left) http://taegang.hubweb.net/board/bbs/board.php?bo_table=p89q5dqe0k&wr_id=6&page=1&sfl=&stx=&sst=wr_comment&sod=desc&sop=and&page=1

(right) http://www.sjchemicals.com/base/english/company/com03.php? (Last accessed 2 Mar 2018)

com_board_basic=read_form&com_board_idx=27&&com_board_search_code=&com_board_search_value1=&com_board_search_value2=&com_board_page=& (Last accessed 2 Mar 2018)

Emissions charge system

The emissions charge system encourages compliance to effluent standards and the reduction of pollution from wastewater discharging facilities. The charge system is composed of basic and excess charges. Basic charges are imposed when the amount of water pollutants discharged from facilities (wastewater discharging facilities, STPs, and WWTPs) is below the discharge allowance standard[39] but exceeds the effluent standard[40].

38. Special Measures Areas are areas where environmental pollution is becoming diversified, severe, prominent, or likely to become prominent due to the concentration of population and industries. They are designated as such for the prevention of environmental pollution and for proper management of the environment through the enforcement of comprehensive environmental pollution measures. (Based on the Framework Act on Environmental Policy Article 22)

39 The discharge allowance standard is a regulatory standard that applies to individual discharging facilities, such as factories, and refers to the maximum amount or concentration of pollutant discharge that is allowed in each facility.

40 The effluent standard applies to the quality of wastewater discharged after comprehensive treatment from STPs, WWTPs, and excreta treatment plants.

Excess charges are imposed when water pollutants discharged are over the discharge allowance standard. However, the emissions charge is reduced or exempted for small facilities, facilities which directly discharge effluent to STPs, and those that reuse wastewater. If a facility voluntarily reports the violation of the effluent standard before being inspected by an environmental agency and takes appropriate emergency actions, such as operation shutdown or wastewater treatment by using external services, the excess charge may be reduced.

2.2.3. Public-private partnership for sewage and wastewater

In 2005, the MOE introduced the Build-Transfer-Lease (BTL) program in which the private sector builds social overhead capitals[43] with their own funds and transfers the ownership to the national government or local governments, or leases them to recover investment costs[42]. At that time, the MOE had a goal to improve sewer pipe distribution rates up to 80 percent and secure sufficient sewer pipes by 2010. This was necessary because, as domestic sewage treatment projects were applied to urban areas in general, the improvement of sewer pipes became second to the construction of STPs[43]. Thus, a BTL project was launched to improve sewer pipes within a short period of time by using private capital to enhance the efficiency of STPs. Further aiming to create a pleasant environment with improved water quality among rivers[44].

As of 2015, 86 BTL sewer construction projects were completed and 16 BTL sewer projects were still under construction or being planned. The length of BTL sewer pipes totaled 8,609 km and the total amount invested in these projects was around 7 trillion KRW[45]. In 2015, 80 STPs were being operated with private investments, six plants were under construction, and four plants were in the planning process on the basis of the Build-Transfer-Operate (BTO) program[46].

41 The concept of "social overhead capital" (SOC) is used to identify the source of certain "basic" services required in the production of virtually all commodities. In its most narrow sense the term refers to transportation, communication, and power facilities. (https://www.encyclopedia.com/social-sciences/applied-and-social-sciences-magazines/capital-social-overhead, Last accessed 22 Feb 2018)

42 Lee, Byung-Kook, et al. "Integrated Management System for Sewerage Facilities and BTL Project for Sewage Pipe in Korea." *Korea Environmental Policy Bulletin*, vol. 1, no. 3, 2005.

43 Ibid.

44 Ibid.

45 Ministry of Environment. *Analysis of Operation and Management Status of Public Treatment Facilities in 2013*.

46 The BTO program is a private financing method in which private investors make investments to build social infrastructure, and then collect fees and commissions for a certain period of time until they recover their investment costs and make profits. Then the ownership of the infrastructure is returned to the local government.

Figure 9: Public-private partnership projects for sewage and wastewater treatment

Sewer pipe under construction (BTL program)[50]

Blueprint of the Pohang Water Reuse Facility (BTO program)[51]

(left) www.dailycc.net, (right) www.jejusori.net

It is important to note that private facilities account for about 14 percent of all STPs in Korea. The total amount of these private investments is 3,717.8 billion KRW with a total processing capacity of 2,083 tons per day[47].

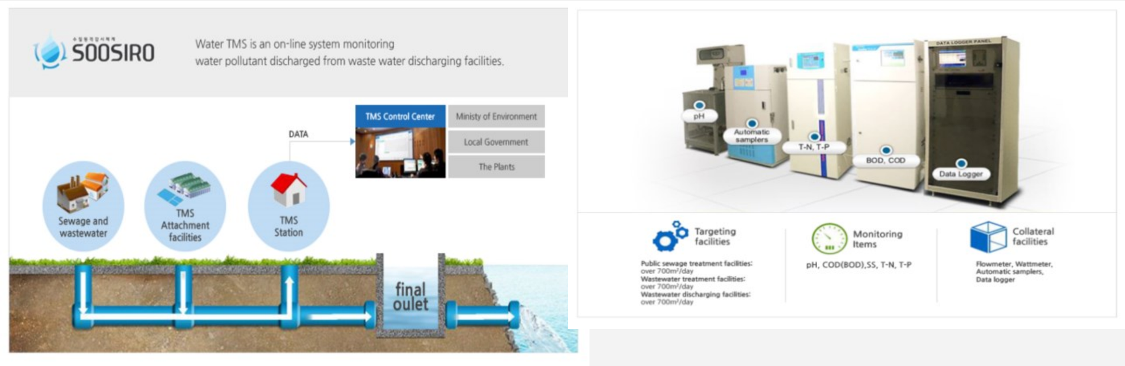
2.3. Tools customized for sewerage systems & wastewater management

2.3.1. Water Tele-monitoring System (TMS)

The Water Tele-monitoring System (TMS) is the representative IT-based water management system in Korea. It is a 24-hour regular monitoring system which observes the emission status of water pollutants by connecting a consecutive auto measurer to the final outlet of nationwide STPs, WWTPs, and commercial sites that discharge wastewater over a certain size[48]. This system was introduced to improve the conventional method of assessing effluent charges from facilities discharging wastewater[49]. It can perform real-time online monitoring and can also help manage facilities, enabling the prevention of illegal dumping into the water. The Water TMS is operated under the purview of the MOE with the participation of river basin environmental offices, local governments, K-eco, along with commercial and industrial facilities that discharge wastewater.

47 Ministry of Environment. *Analysis of Operation and Management Status of Public Treatment Facilities in 2013.*
48 More details available at www.soosiro.or.kr
49 Chung, Eu Gene. "Water Quality Monitoring Using IT." *Korea Environmental Policy Bulletin*, vol. 4, no. 8, 2010.

Figure 10: Water Quality Monitoring System (Water TMS) illustration



The Water TMS is an online system that monitors water pollutants that discharge wastewater.

Korea Environment Corporation, www.keco.or.kr. Last accessed: November 26, 2018.

2.3.2 Ecological toxicity management system

The ecological toxicity management system aims to examine hazardous materials in the effluent of wastewater and to effectively alleviate their effect on the aquatic ecosystem. Water fleas (*Daphnia Magna*) are put into the effluent as a test indicator to see if they can survive for more than 24 hours. The toxic unit (TU) represents the level of the Whole Effluent Toxicity (WET). The WET test method consists of exposing living aquatic organisms such as water fleas to various concentrations of a sample of waste water.

Figure 11: Whole Effluent Toxicity (WET) Management System

Whole Effluent Toxicity (WET) Management System		
35 Wastewater discharging facilities*	Public wastewater treatment plants	Public sewage treatment plants**

*35 industries including petrochemical facilities categorized under the enforcement regulation of the Water Quality and Ecosystem Conservation Act

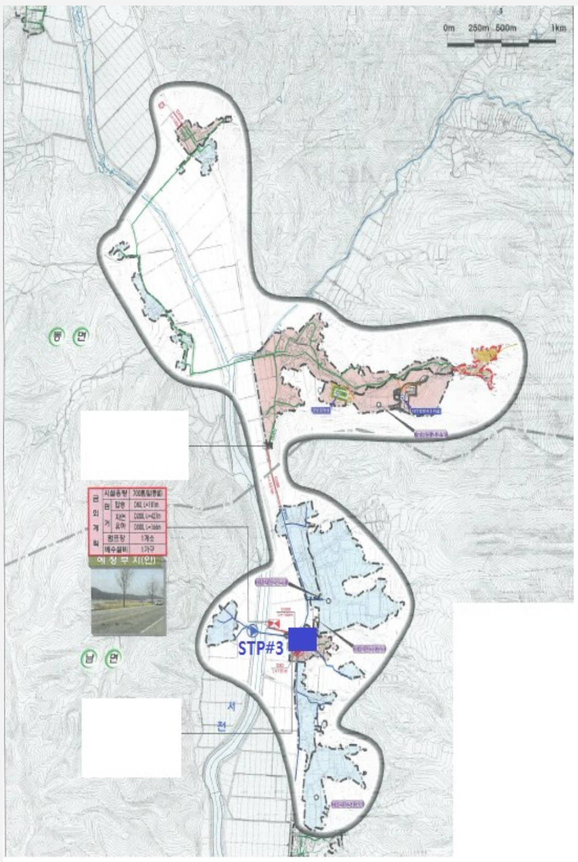
**STPs of which the capacity is 500 m^3or more m^3 per day and where wastewater discharged by 35 industries flows in.

Korea Environment Corporation, www.keco.or.kr. Last accessed: November 26, 2018.

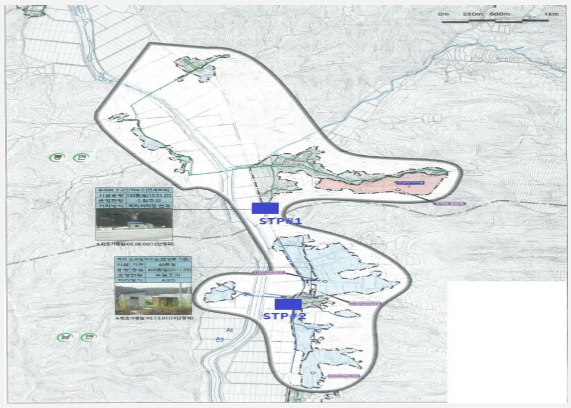
2.3.3. Decentralized sewerage system

A decentralized sewerage system is capable of collecting, treating, reusing, or disposing of sewage at or near the source of sewage generation[51]. Korea initially constructed large -scale STPs. However, this system turned out to be inefficient for treating sewage in sparsely-populated rural areas. To address this problem, decentralized sewerage systems were introduced. The decentralized system reduced the budget amount needed to finance new facilities in rural areas. Additionally, the system helped prevent water pollution as well as streams drying up, and encouraged the reuse of organic matters in rural areas.

Figure 12: Comparison of the decentralized sewerage system with the centralized sewerage system



Blueprint of sewerage system in Yanggu-gun, Gangwon-do. In this centralized sewerage system, all areas are treated by STP#3.



Blueprint of sewerage system in Yanggu-gun, Gangwon-do. In this decentralized sewerage system, the upper area is treated by STP#1 and the lower area by STP#2.

Small-scale STP

in the decentralized sewerage system

Water Journal, www.waterjournal.co.kr

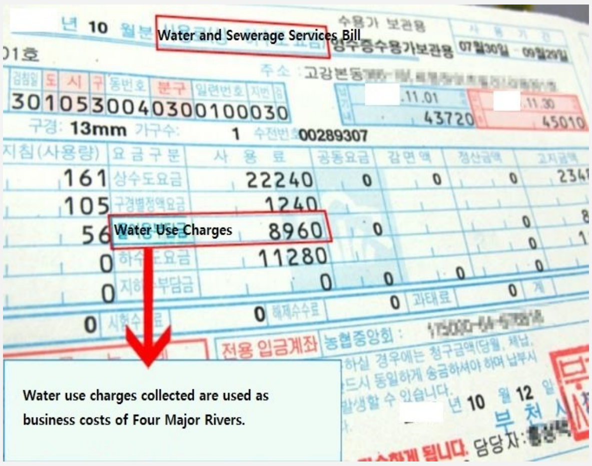
50 Park, Wooha. "Decentralized wastewater treatment system." *Water for the Future*, vol. 41, no. 10, Oct. 2018, www.kwra.or.kr/wonmun/KWRA_1_2008_10_59(C).pdf. Last accessed: November 26, 2018

51 It is a fund created by collecting water use charges in proportion to the amount of water directly used or used after purification by the end user, in order to raise funds for resident support and water quality improvement

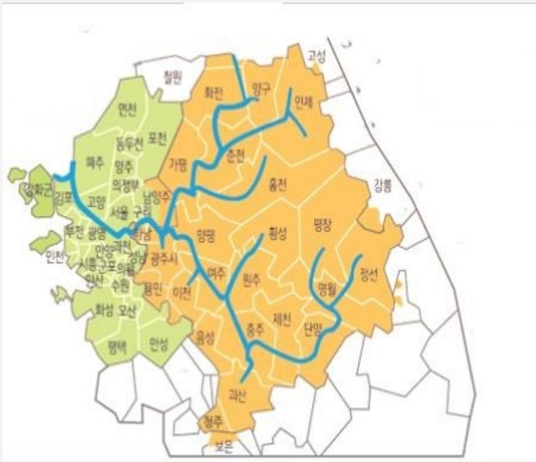
2.3.4. Water use charge system

The river management fund[51] is used as an effective financial tool for managing river basins. In 1999, the water use charge system was implemented[52]. This system collects charges from downstream users, who are supplied with tap water produced from upstream water. The charges are added to the river management fund and used to carry out projects for water quality improvement and support upstream residents who are negatively affected by regulations on water sources[53]. Likewise, these financial measures mediate interests between upstream and downstream users.

Figure 13: Water use charge system



Example of a water bill. Collected water use charges are used as Four Major River business costs. Regarding the Han River watershed, water use charges are 170 KRW/m³.



Green part: Area paying water use charges (downstream)
Yellow part: Han River watershed management fund business area (upstream)

Left: blog.naver.com/daegunusu04. Last accessed on November 26, 2018. Right: www.hanriver.or.kr. Last accessed on November 26, 2018

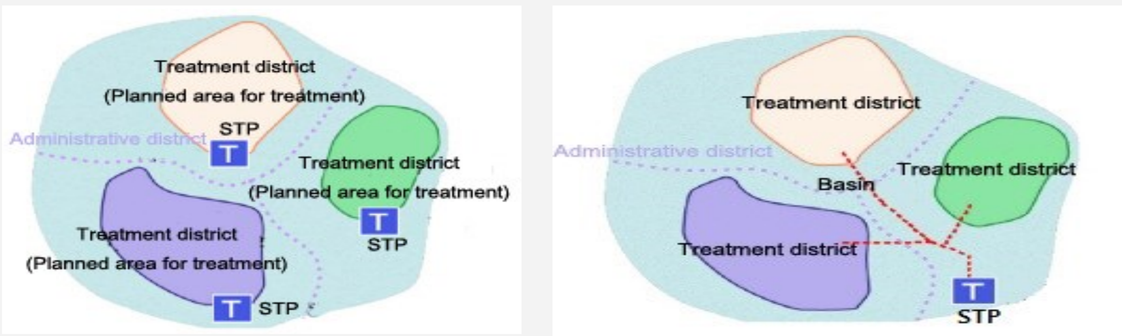
52 *My Water: K-Water*, http://www.water.or.kr (Last accessed 22 Feb 2018)
53 Ministry of Environment. 2004. "*Water Policies and Innovative Practices*."

The water use charge system is based on the "polluters-pay principle." Charges are imposed on end users who are supplied with water collected from the upstream water resources. The charges are proportionate to the amount of water used and are included in the water bill. The rates are adjusted by the River Management Committee every other year. During the early stages of implementation, rates ranged from 80 to 110 KRW per ton[54]. They gradually increased to 160 KRW by 2013 and to 170 KRW by 2017[55]. In 2012, a total of 833 billion KRW was collected from the Four Major River watershed, including 447 billion KRW from the Han River[56].

2.3.5. Integrated Watershed Sewage Works Program

The Integrated Watershed Sewage Works Program (IWSWP) includes the planning, installation, and management of sewage facilities either by the local government or the central government for a given watershed. Furthermore, the water quality standard is established by the local governments in geographical proximity[57]. If a public watershed covers more than two municipal administrative districts, each local government is not individually responsible for sewerage management, but regards the watershed as an integrated, single area for sewerage maintenance. A significant benefit of this program is cost saving through facility consolidation. It has also shown that the IWSWP is more efficient at improving the quality of the public water body than the Conventional Local Sewage Works Program (CLSWP). In addition, economic benefits can be achieved by integrating facilities, operations, and maintenance.

Figure 14: Integrated Watershed Sewage Works Program (IWSWP)



The current sewerage system maintenance plan for cities and counties | **Integrated sewerage system maintenance plan in the same watershed**

Water Journal, www.waterjournal.co.kr. Last accessed: November 26, 2018.

54 Ministry of Environment. *ECOREA Environmental Review 2015*.
55 Ibid.
56 Ibid.
57 Yoon, Hyunsik, et al. "Economic Analysis for the Integrated Watershed Sewage Works Program in the Sample Area." *Journal of the Korean Society of Water and Wastewater*, vol. 26, no. 4, 2012.

Within the IWSWP, sewerage maintenance items are identified by municipalities along with basic investments towards the watershed. The planning process takes into account economic considerations and water quality improvement within every watershed area. Cost reduction is achieved through facility integration, which is determined by establishing and expanding existing local municipal treatment plants and by comparing the efficiency of the IWSWPs.

2.4. Reuse, reclamation, and energy saving in STPs and WWTPs

2.4.1. Reuse and reclamation in STPs and WWTPs

The 'Act on Promotion and Support of the Reuse of Water' established in 2010 stipulates that STPs treating over 5,000 m^3 of wastewater should reuse more than 10 percent of the treated amount as reused wastewater.

By the end of 2014, more than 560 public STPs out of 597 (that treat more than 500 m^3 of wastewater per day) were reusing treated sewage, comprising a 13.5 percent reuse rate of treated sewage. Additionally, 53 percent of reused water was utilized for cleaning, gardening, and for processing among STPs. The water used outside of the STP was mainly for river maintenance purposes.

Figure 15: Reuse and reclamation in STPs

Sewage Reuse Plant in Osan

Ministry of Environment, 2016, *Historical Development of Korea's Sewerage System*.

2.4.2. Energy saving and renewable energies in STPs and WWTPs

Energy savings and renewable energy

In 2011, the 'Energy Independence of Sewage Treatment Plants' plan was declared to increase the energy independence rate of 343 STPs to 50 percent by 2030. It aimed to break away from the negative perception surrounding STPs and establish a sustainable sewerage system that converted polluted wastewater into valuable resources.

In 2007, greenhouse gas emissions from environmental infrastructures in Korea were quite high, at 3.5 percent[58]. Sewage treatment plants accounted for a large portion of these environmental facilities and used a considerable amount of energy, accounting for 0.5 percent of the total annual electricity consumed in Korea[59]. However, sewage treatment facilities potentially have abundant energy resources, such as bio-digestion gas and heat energy from sewage[60]. Bio-digestion gas and sewage sludge are among the byproducts generated in STPs which can be converted into energy. Bio-digestion gas can generate a considerable amount of energy through various technologies, to be used for purposes such as generator fuel or as an energy source for heating digestion tanks.

Figure 16: Renewable energy utilization in STPs

Photovoltaic power plant in the Jungnang Sewage Treatment Center

Bio-digestion pipe located in the Nanji Sewage Treatment Center

Ministry of Environment, 2016, *Historical Development of Korea's Sewerage System*

58 Ministry of Environment, 2016, *Historical Development of Korea's Sewerage System*.
59 Ibid.
60 Ibid.

2.5. New programs for preventing urban flooding

Due to diversity of factors, including climate change, intense rainfall is becoming more frequent in Korea. This is particularly worrisome for urban areas, for example, some parts of downtown Seoul were flooded by heavy downpours in 2010 and 2011. To address this problem, the government prepared a "Comprehensive Plan on Sewage Maintenance against Urban Flooding" in May 2012. The plan recommended improving the drainage capacity of the public sewerage system by constructing storm water detention facilities and large-scale tunnels for storing storm water. In addition, it outlined advanced design and operation techniques for these particular facilities to prevent flooding. According to the plan, flood-prone areas were to be designated as "Priority Areas for Sewage Maintenance" with proper management of these areas. By the end of 2013, 21 sites were designated as Priority Areas for Sewage Maintenance. By 2017, the number of designated sites increased to 60.

Typically, large-scale storm water storage systems are constructed in sites where it is difficult to prevent urban flooding by improving sewer capacities and expanding detention facilities. Accordingly, sewerage infrastructure, such as storm sewers, sewage detention facilities, and storm water pumping stations, were expanded. As a pilot project, 232.7 billion KRW was invested in six selected sites for upgrading sewage infrastructure. Furthermore, a technical support team is now operated by K-eco to relieve the administrative burden and to shorten the construction period involving storm water storage systems.

Figure 17: Storm water storage and storm water pumping

Storm water storage facility in Seoul

Storm Water Pumping Station in Seoul

(left) www.seoultimes.net. Last accessed: November 26, 2018.

(right) Ministry of Environment. *Historical Development of Korea's Sewerage System*.

2.6. Challenges and vision

Korea has been responding to global challenges, such as climate change, by developing sewerage systems and improving sewage and wastewater management systems within the context of these challenges. This is demonstrated by the introduction of the MOE 2050 Sewerage Policy Vision. The MOE, in collaboration with K-eco, established and presented the 2050 Sewerage Policy Vision aiming to expand the role of sewerage as a response to climate change challenges, and to foster sewerage management as a new industry. This vision includes five key policies under the overarching goal of "creating future value and providing people with safe and tangible services", including: safe sewerage, tangible services, restoration of the water environment, sustainable funding, and resource recovery from sewage and wastewater.

Safe sewerage systems for flood-proof cities

Since 2012, the government has been making efforts to improve the storm water management function of the public sewerage system. This includes expanding storm water facilities and tunnels; introducing advanced design and operation techniques for removing storm water; and strengthening flood prevention institutions.

Tangible services and resident-friendly sewerage

Sewerage systems are still regarded as "unpleasant facilities" due to bad odor emanating from them. It is necessary to establish and implement countermeasures to reduce the odor, by introducing odor reduction technologies in the septic tanks and sewer pipes, and increasing the capacity of disinfection facilities.

Restoration of the water environment

Since 2000, sewerage policies have been implemented within the integrated watershed management system. This includes the four major rivers in Korea leading to a healthy and clean water environment.

Sustainable funding for sewerage

In the future, the sewerage system needs government financial investment for public services, such as the restoration of the water environment in response to the impacts of climate change.

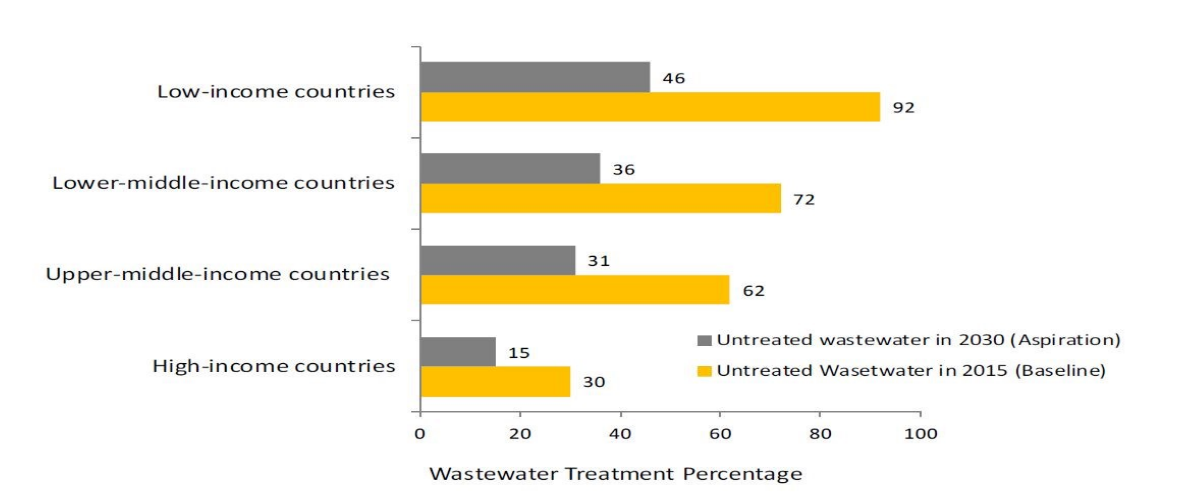
Resource recovery from sewage and wastewater

Since 2009, a ban on dumping sewage sludge in the ocean has been enforced, and Korea has been recycling sewage sludge. The recycled product is used as: compost, cover materials for landfills, and lightweight aggregates. Future STPs and WWTPs can utilize sludge generated from energy consuming facilities, helping to improve water quality by reducing pollutants.

3
Gap Analysis from Countries around the World

Sewage and wastewater treatment holds numerous advantages for communities, but progress on these facilities and fit-for-purpose reuse is still slow in many developing countries. Numerous countries are at a crossroads, trying to decide between implementing policies for strategic investments or accelerating sewage and wastewater treatment. Managing sewage and wastewater safely is key to addressing water-related sustainable development as well as SDG Target 6.3: *By 2030, improve water quality by reducing pollution, eliminating dumping and minimizing release of hazardous chemicals and materials, halving the proportion of untreated wastewater and substantially increasing recycling and safe reuse globally.*

Figure 18: Percentage of untreated sewage and wastewater in 2015 and SDG 6.3 aspirations for 2030 with 50 percent reduction over the 2015 baseline



Qadir, M., and J. Mwachiro. 2017. *Towards a World Free of Untreated Wastewater.* UNU-INWEH Policy Brief, Issue 2.

Lower-middle-income countries (LMICs) on average treat 28 percent of the sewage and wastewater that is generated, while only 8 percent of sewage and wastewater is treated in lower-income countries (LICs)[61]. Even if SDG Target 6.3 is achieved worldwide by 2030, 46 percent of sewage and wastewater will still be left untreated in LICs, 36 percent in LMICs, 31 percent in upper-middle-income countries (UMICs), and 15 percent in high-income countries (HICs)[62]. Also, LMICs and LICs are expected to reduce greater amounts of untreated sewage and wastewater than UMICs and HICs.

3.1. Legal and institutional framework

Poor governance contributes to lack of sewage and wastewater treatment. These shortcomings include ineffective institutions, lack of policy enforcement, corruption, lack of infrastructure, and the shortage of investment into human resources. The lack of data on sewage and wastewater is another critical factor that limits the possibility of effective policymaking towards water quality. For example, Sub-Saharan Africa in general lacks quantitative data on sewage and wastewater, with comprehensive data only available for Senegal, Seychelles, and South Africa. The data from Seychelles and South Africa is limited, going as far as only 2000. Additionally, in many countries, legislation within the water sector usually does not take sewage and wastewater into consideration. For instance, there is almost no mention of sewage or wastewater in federal or state laws in Nigeria[63].

3.2. Sewage and wastewater management

3.2.1. Large-scale STPs especially for MICs and large cities in LDCs

People living in rural areas in LDCs still have difficulty accessing drinking water. There remains a need for the installation of facilities that ensure healthy and sanitary living conditions. In rural areas, untreated sewage infiltrates into the soil and becomes a source of waterborne pathogens in the groundwater, which is used as drinking water. Thus, despite improvements in the supply of drinking water, the ratio of children under five suffering from diarrhea has not improved significantly. As many villages in developing countries rely on groundwater as a source for potable water. In rural areas, especially in sparsely-populated areas, small-scale STPs (as illustrated in Figure 12) can be an effective solution. Safely managed sewage and wastewater are valuable sources for recoverable materials such as water, energy, and nutrients. These benefits from STPs can exceed the costs associated with sewage and wastewater treatment.

61 Qadir, M., and J. Mwachiro. 2017. *Towards a World Free of Untreated Wastewater.* UNU-INWEH Policy Brief, Issue 2.
62 Ibid.
63 WWAP (United Nations World Water Assessment Programme). 2017. *The United Nations World Water Development Report 2017. Wastewater: The Untapped Resource.* Paris, UNESCO.

3.2.2. Large-scale STPs especially for MICs and large cities in LDCs

Currently, around 50 percent of the world's population lives in cities[64]. By 2050, this statistic is expected to rise to about 70 percent. As the urban population is grows, building sewerage systems as social infrastructure becomes crucial. It is also essential for improving the quality of urban water sources and rivers, and necessary for establishing a systematic, large-scale sewerage facility to prevent urban flooding.

3.2.3. Capacity building for the O&M of STPs and WWTPs

Many LDCs and MICs lack education and training programs related to sewerage systems, which make it more difficult to adequately use treatment facilities, leading to low efficiency. In addition to the need for financing, it is important to have the institutional capacity for conducting STP and WWTP projects. The sewerage system can be developed more sustainably if a fully trained, qualified specialist is involved in designing, installing, and operating the sewerage system.

3.3. Financing sewerage and wastewater services

Some MICs and LDCs have funds dedicated to sewerage, but the allocation of these funds is generally low in priority compared to funds allocated for waterworks. Sustainable funding is important, as sewerage requires considerable operation and installation costs. Unfortunately, sewerage investment costs account for a large portion of the government's limited annual budget. This can be inopportune when economic revitalization is an important consideration for such governments.

64 The United Nations. *World's population increasingly urban with more than half living in urban areas,* http://www.un.org/en/development/desa/news/population/world-urbanization-prospects-2014.html, Last accessed 27 Feb 2018

4. Recommendations for LDCs and MICs

This part of the report reviews and consolidates points and suggestions found throughout this paper.

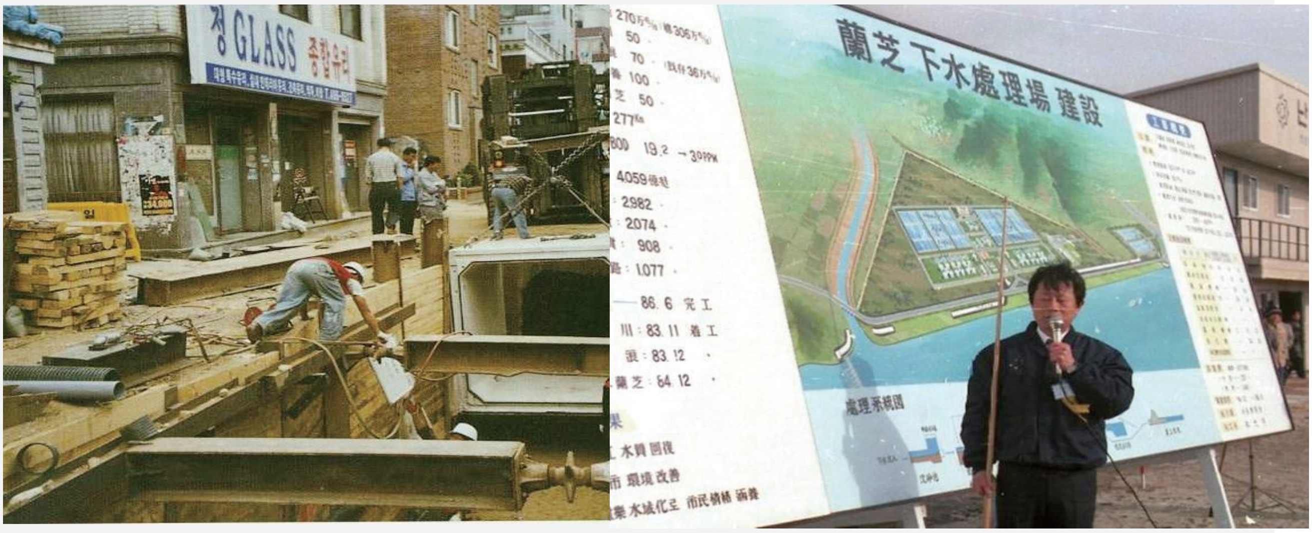
Introduction of a decentralized sewerage system

As noted before, a decentralized sewerage system enables the collection, treatment, and reuse of sewage at the source, where sewage is generated. This system is cost-efficient for treating sewage in sparsely-populated rural areas, and reduces the budget needed to finance new facilities in rural areas. In addition, the system helps prevent water pollution as well as the drying up of streams, and encourages the reuse of organic matter from sewage and wastewater in rural areas.

Simultaneous installation of both STPs and sewer pipes

If sewer pipes are not installed simultaneously while building STPs, it is difficult to adequately collect the generated sewage. Furthermore, a low concentration of sewage flow into STPs can cause STPs to have low efficiency. This can also lead to street flooding after storms, as storm water cannot flow into sewer pipes. Therefore, a well-balanced supply of STPs and sewer pipes is important and indispensable to the sewerage system.

Figure 19: STPs and sewer pipes in Korea



Installation of sewer pipes **Nanji STP**

(left) www.dailyin.com, (right) Ministry of Environment,2016, *Historical Development of Korea's Sewerage System*.

Expansion of infrastructure for urban flood prevention

With climate change, there has been an increase of heavy rainfall in some areas around the world. Intense downpours in urban areas can often cause street flooding.

To address this problem, governments need to prepare a comprehensive plan on sewerage systems against urban flooding. The plan should cover methodology, design, and operation techniques to improve the drainage capacity of public sewerage systems particularly in flood-prone areas.

In addition, sewage infrastructure such as storm sewer pipes, storm water detention facilities, and storm water pumping stations can be expanded. A pilot project for upgrading sewage infrastructure in select sites can be considered. A new storm water storage system can be constructed among sites that are unable to fully prevent urban flooding with existing storm sewer pipes and detention facilities. Furthermore, a technical support team can relieve the administrative burden of such projects which can also lead to shorter construction periods.

Consideration of water reuse in water-stressed countries

Most LDCs and MICs lack laws regarding the reuse of treated wastewater. A comprehensive law which covers the management of greywater[65] facilities, water supply, and sewage could be considered a viable solution for the reuse of treated wastewater. It can regulate public WWTPs to reuse more than a certain portion (e.g. 10 percent) of treated wastewater. In areas with frequent droughts and insufficient water resources, reusing treated water is all the more important.

Case study 3

Direct Potable Reuse (DPR) in Windhoek, Namibia

In the case of Windhoek, Namibia, the use of reclaimed water was the only available option to overcome a water shortage after a crisis in 1957 when the local aquifer was overused by 57%[66]. As a result, direct potable reuse[67] was first implemented at the wastewater reclamation plant. Strict safety measures were also applied for the first time at this wastewater reclamation plant. Consequently, the safety of the plant was verified and no health problems occurred during its operation for the next 40 years. Furthermore, in 2002, a new plant was built with upgraded technology[68].

65 Greywater refers to all wastewater generated in households or office building from streams without fecal contami nation i.e. all streams except for the wastewater from toilets.

66 World Bank, http://siteresources.worldbank.org/EXTWAT/Resources/46021221215104787836/10.CC_Water_Supply_Arid_Environment_Windhoeki.pdf, Last accessed 27 Feb 2018

67 The reclamation of water from sewage and wastewater for drinking can be referred to as either direct or indirect potable (drinking) reuse. Direct potable reuse (DPR) can be defined as either the introduction of recycled water di rectly into the potable water supply distribution system downstream of the treatment plant, or into the raw water supply immediately upstream of a treatment plant.

68 WWAP (United Nations World Water Assessment Programme). 2017. *The United Nations World Water Development Report 2017. Wastewater: The Untapped Resource.* Paris, UNESCO.

Establishment of a 24-hour Water TMS in areas with STPs or WWTPs

As noted before, establishing a Water TMS which monitors water quality by analyzing the effluent pollutants from the final outlet of public STPs, WWTPs, and wastewater discharging facilities automatically and in real-time can be considered. It can be monitored through an the online water inspection system. Regulators can require industries to install an automatic water quality measurement system. This water quality monitoring network can be used in countries that aim to thoroughly or partially apply the legal standards associated with STPs.

Consideration of various ways to finance sewerage and wastewater services

In the early stages of economic growth, a combination of loans and grants can be used for financing sewerage systems, especially in large cities as in the case of Korea. In terms of operation costs, active support by the central government is needed to reduce the burden of increased sewerage charges. Furthermore, establishing a river management fund is another solution in which people in downstream areas use water from upstream areas. Additionally, the introduction of private capital for funding, as well as a tax increases for local residents, can be considered.

Establishment of permit and reporting system for wastewater discharging facilities

A permit and reporting system for wastewater discharging facilities can be considered. Facilities that may significantly influence water quality must obtain a construction permit beforehand and report any concerns. To monitor compliance with effluent standards, wastewater discharging facilities, STPs, and WWTPs of a certain size should be required to be equipped with monitoring devices.

Consideration of governmental support for WWTPs

LDCs and MICs that are undergoing economic development find that generating industrial wastewater is inevitable. Therefore, it would be helpful if the industries responsible, bear the installation and operation costs for treating wastewater as per the polluters-pay principle. However, in order to avoid a decrease in private sector investment, governmental support for establishing WWTPs in industrial complexes should be seriously considered.

Implementation of an emissions charge system

LDCs and MICs can consider introducing an emissions charge system to encourage compliance to effluent standards and to reduce pollution through wastewater discharging facilities. The system can be composed of basic and excess charges. Basic charges are imposed when the amount of water pollutants discharged from facilities (wastewater discharging facilities, STPs, and WWTPs) is below the discharge allowance standard but exceeds the effluent standard. Excess charges are imposed when water pollutants discharged are in excess of the discharge allowance.

Establishment of a legal and institutional framework on sewerage systems

Legislation devoted to sewerage is needed to maintain and improve sewerage systems. These policies should cover legal institutions, the scale of sewerage installation, budgets, and penalties. For example, Korea's Sewerage Act covers regulations on sewerage installation and management, excreta disposal, businesses related to sewage and excreta, and costs.

Moreover, a sound sewerage management system is critical for using a limited government budget in an efficient manner. Due to budget constraints, a treatment plant should first be built in the vicinity as a matter of highest priority. For instance, Korea introduced STPs mainly in large cities when it first started to build STPs, and established a basic plan for sewage treatment in each municipality.

Establishing a public organization specialized in sewerage installation and operation can be considered. STPs should be used long-term as they are costly. Therefore, a qualified operator is needed to appropriately manage the sewage to ensure the longevity of these facilities. Unfortunately, STPs in LDCs and MICs are generally not managed properly, causing operational problems. Considering that the longevity of STPs is dependent on how it is operated and managed, establishing a responsible organization is of utmost importance. In Korea, the government has entrusted much of this responsibility to professional operating organizations like K-eco.

The figure below describes the system of installation and operation of sewerage in Korea.

Figure 20: Installation and operation procedures of sewerage systems in Korea

Plan		Installation		Operation		Inspection
Framework Plan for Sewerage Expansion and Rehabilitation	▷	Installation of STPs and sewer pipes	▷	Operation of STPs (Professional operating organization)	▷	Assessment of STPs by professional consulting companies like K-eco

Establishment of large-scale STPs, especially in MICs and large cities in LDCs

When establishing large-scale STPs, it is necessary to use the appropriate technology within the constraints of construction and operation costs. Technology should be selected on the basis of sustainability of energy supplies for operating plants in the country, the country's target for water quality, and whether STP parts can be continuously produced domestically. Moreover, effluent standards for STPs, their legal force, along with the policies related to the management of reusing treated sewage of STPs should be considered.

Consideration of capacity building for the O&M of STPs and WWTPs

The sewerage system has a high chance of maintaining sustainability if a fully trained, qualified specialist designs, installs, and operates it. In the case of Korea, the country relied on foreign capital, technology, and manpower when establishing the country's first treatment plant. Due to the lack of specialists who were needed to design, install, and operate the sewerage system domestically, it also became important to nurture them. To address this shortage, Korea conducted training programs for operators. Experts who received systematic training and education from universities were placed in the field, so the country would no longer have to depend on foreign support for sewerage technology. Similarly, in developing countries, a professional certificate program for operators can be considered, and a sewerage-related curriculum can be added to the local education system so that specialized research can be carried out. Moreover, raising awareness about the importance of sewerage in the local community is important, and regular training and refresher programs for operators run by the government should be considered.

Table 3: Recommended policies for LDCs and MICs in a matrix

Category	LDCs	MICs
Establishment of a legal and institutional framework on sewerage systems	○	○
Establishment of large-scale STPs especially in MICs and large cit-ies in LDCs	○	○
Installation of both STPs and sewer pipes at the same time	○	○
Expansion of infrastructure for urban flood prevention	△	○
Water reuse in water-stressed countries	○	○
Consideration of various ways to finance sewerage and wastewater services	△	○
Establishment of a permit and reporting system for wastewater discharging facilities	△	○
Consideration of water reuse in water-stressed countries	○	○
Establishment of a 24-hour Water TMS in areas with STPs/WWTPs	X	△
Consideration of governmental support for WWTPs	○	○
Implementation of an emissions charge system	○	○
Consideration of capacity building for the O&M of STPs and WWTPs	○	○

○: Recommended / △: Can be considered for introduction / X : Too early to introduce

5. Conclusion

Over a period of 50 years, Korea has made remarkable progress in improving its water quality sector alongside rapid economic development. The completion of the country's first STP in 1976, the Cheonggyecheon STP, became a starting point for the successful development of Korea's sewerage system. The distribution rate of sewerage systems skyrocketed from 8.3 percent in 1980 to 92.9 percent in 2015, and the distribution rate of sewer pipes rose from 55.9 percent in 1980 to 79.9 percent in 2015. As sewerage systems helped reduce water pollution and thus improve public hygiene, outbreaks of waterborne diseases have greatly decreased as a result.

This paper has touched upon Korea's historical conditions as well as various policies and tools for sewage and wastewater management and treatment. Based on the country's experience, a gap analysis on the sewerage system of developing countries has been introduced, followed by a set of recommendations on how to fill this gap. However, the scope of the paper does not allow customized solutions for different countries with different income levels. An in-depth analysis is needed regarding the different economic and environmental factors of each country, such as policies, governance structure, and existing hygiene and sanitation systems, among other factors. Further studies may consider people living in slum areas where sanitation crews, such as garbage collection trucks, do not have access. Another limitation is that this paper does not highlight Korea's unique sewerage system compared to other developed countries. However, this paper can serve as a basis on which further research on various countries' sewerage system can be built.

As the transformation of Korea's sewerage system is not yet complete, this paper is a living document, and it is hoped that the lessons learned from the country's developmental history can be applied to developing countries and may provide concrete ideas towards improving global sewerage systems.

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