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Wet weather sewerage management in Korea

S. Han, C.-H. Lee, J.-S.Yook, J.-G. Han, J.-H. Hwang & I.-H. Choi
Department of Sewerage, Korea Environment Corporation, South Korea

Abstract

Korean sewerage policy focused on sewer pipelines and sewage drainage for the prevention of flooding due to rapid urbanization before the 1970s. From the 1980s to the 2000s, the policy focused on publicly owned treatment works (POTW) construction in order to improve water quality. Since the 2000s, Korean sewerage policy has significantly achieved an up to 92% of sewerage service penetration rate through sanitary sewer system rehabilitation, POTW expansion and enhancing treatment processes. However, inflow/infiltration (I/I) to pipelines and manholes which is caused by incomplete sanitary sewer construction has resulted in low sewage quality influent in the POTW. In addition, untreated sewage discharge due to the lack of ability to cope with the influent to POTW during wet weather problems such as combined sewer overflows (CSOs) and sanitary sewer overflows (SSOs) are caused by compact capacity of the POTW according to the economical facility plan and confined policy management on dry weather. Moreover, it affects the water quality deterioration problem for public water. In this report, we reviewed the comprehensive problems and counter measures of the sewer system including collection, transportation, and treatment facility of sewage and established wet weather sewage management. And we have made exemplary sewerage works and derived guidelines for sewer system management during wet weather with two selected cities (Seo-san, Nam-won) in Korea. We are going to enlarge the derived guideline to all POTW (over 500m^3/d) in Korea to solve the problem about wet weather flow. Finally, we will be able to protect our water resources sustainably.
Keywords: CSOs, SSOs, inflow/infiltration, wet weather, sewerage treatment, RDII.

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1 Introduction

Korean sewerage policy focused on sewage drainage and sewer pipelines for the prevention of flooding due to rapid urbanization before the 1970s. And the policy focused on publicly owned treatment works (POTW) construction and interception pipelines in order to improve water quality from the 1980s to the 2000s. Since the 2000s, Korean sewerage policy has significantly reached up to 92% of the sewerage service penetration rate through sanitary sewer system rehabilitation, POTW expansion and enhanced treatment processes. It gave expectation of improvement of water quality due to an increasing number of POTW from 26ea to 569ea and of sewage throughput from 5.8milion m^3/d to 19.8milion m^3/d. And the advanced treatment process was conducted at the POTW to prevent eutrophication in public water since the effluent regulation was enhanced from 2001, in accordance with the worsening problem of total nitrogen (T-N) and total phosphorous (T-P). Through a tele-monitoring system which is real time monitoring of POTW (over 700 m^3/d) effluent is being operated to prevent accidents as a result of water pollution. As the investment also continually expanded to the sewer system, approximately 126,606km have been installed which shows the distribution of 81,191km (64.1%) with a sanitary sewer and 45,415km (35.9%) with a combined sewer. The influent quality into POTW also improved by about 40% (BOD basis) as a result of sanitary sewer construction and continuous maintenance of pipelines [1]. However, inflow/infiltration (I/I) to pipelines and manholes, caused by incomplete sanitary sewer construction such as unconnected house, uninstalled regulator, unclosed regulator, and faulty lateral connection resulted in low sewage quality influent in POTW (USEPA [2]). And untreated sewage discharge due to lack of ability to cope with influent to the POTW during wet weather problems such as combined sewer overflows (CSOs) and sanitary sewer overflows (SSOs) are caused by POTW, which has no primary settling tank and equalization tank, according to the economical facility plan and confined policy management on dry weather [3, 4].

Especially, if the influent exceeds the approved design capacity due to inflow/infiltration during wet weather, the operating capacity of POTW might be able to decrease and sanitary sewer overflows (SSOs) would occur in a sanitary sewer service area. And untreated sewage discharge to surface water would occur because of a lack of ability to cope with the maximum daily flow of POTW which induces CSOs and by-pass during wet weather.

These problems led to decreasing efficiency of the sewage treatment system caused by impulsion of the unit project for solution of the pending issue without comprehensive analysis and review of sewerage. In particular, provision and operation of sewerage facilities has grown to the level of advanced countries for sewage treatment during dry weather through intensive investment during a short period. However, it is still vulnerable because we don't have any counterplan against sewage treatment during wet weather. That's why we reviewed the comprehensive problems and counter measures of the sewer system including collection, transportation, and treatment facility of sewage and established wet weather sewage management. We have made exemplary sewerage works and derived guidelines for sewer system management during wet weather with the two selected cities (Seo-san, Nam-won) in Korea. Then, we are going to spread the derived guideline to all POTW (over 500m^3/d) in Korea to solve the problem about wet weather flow. Finally, we will be able to protect our water resources sustainably.

2 Problems of sewerage facilities during wet weather

The presented general problems of the steps such as collection, transportation and treatment during wet weather through exemplary sewerage works were ascertained.

2.1 Collection step

When a sanitary sewer system is under construction, it is recommended that private sewer laterals such as house-inlet installed and septic tank be removed to send night-soil directly into the soil-pipe. However, rainfall-derived inflow/infiltration (RDII) because of imperfect construction of private sewer laterals has been the reason for flow increase and water quality degradation of influent to POTW. And untreated sewage also is discharged into surface water which causes water pollution.

Table 1 shows the construction status of private sewer laterals and Table 2 shows pollution mass load (basis BOD) of an imperfectly constructed house.

Table 1: The construction status of private sewer laterals (Seo-san).

	Total house (A=B+C)	Constructed house (B)	Imperfectly constructed house (C)	The ratio (C/A)
Seo-san	9,513	8,748	765	8.4%

Table 2: Mass load from an imperfectly constructed house (Seo-san).

	Imperfectly constructed house	Population living in imperfectly constructed houses	Pollution load rate (gram/pd)	Mass load (kg/d)	Annual mass load (kg/y)
Seo-san	765	3,460	66.9	231	84,488

As Tables 1 and 2 show, a significant amount of mass load is discharged from an imperfectly constructed house, obviously having an adverse effect on public water in Korea.

2.2 Transportation step

2.2.1 Regulator

It is uneconomical to treat both storm water and sewage at a POTW in a combined sewer system because it involves an increase in pipeline and sewage treatment plants. So, we install a regulator to send proper sewage (design sewage flow during

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wet weather) into an interceptor sewer and let storm water which doesn't flow into the interceptor sewer discharge to surface water [5]. The design sewage flow during wet weather is defined in accordance with dilution of scale which is concerned with conditions and characteristics of the drainage district. In principle, it is more than three times the peak hour flow [6]. In order to intercept properly, a certain amount is important to reduce the amount of overflow and discharge and let the function of the interceptor sewer, sewage treatment plants and storage facilities play their roles to the maximum. If sewage which is more than design sewage flow flows into the POTW from the regulator, the influent might exceed the designed capacity of the POTW and untreated sewage would be discharged. In contrast, if sewage which is less than the design sewage flow flows into the POTW from the regulator, a lot of combined sewer overflows (CSOs) would be discharged from the regulator and pipelines and water pollution would result due to the direct discharge of sewage. Basically, CSOs, which is untreated sewage incurred from the regulator and pumping station, and effluent, which is discharged from the POTW during wet weather, are a pollution mass load. It is necessary that the regulator is managed properly for the control of CSOs.

Figures 1 and 2 show the number and locations of regulators of Nam-won and Seo-san.

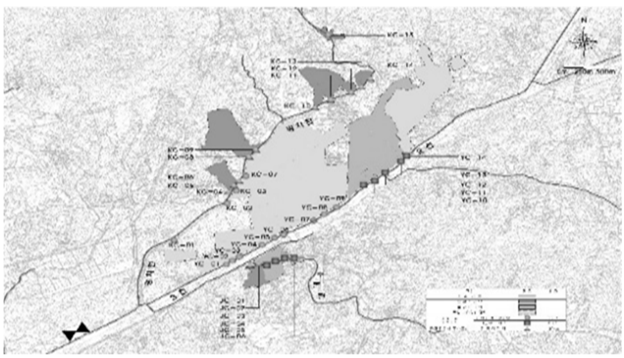

Figure 1: The number and locations of regulators in Nam-won.

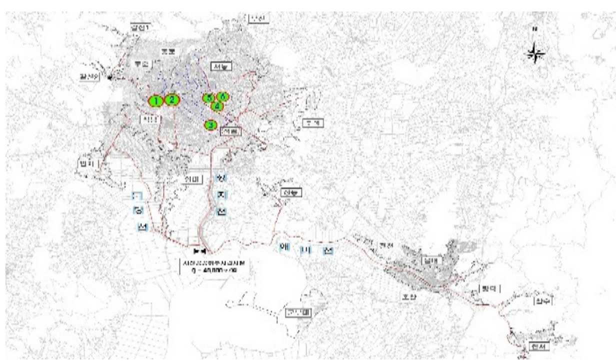

Figure 2: The number and locations of regulators in Seo-san.

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Table 3: The number of regulators in the two cities.

	The number of regulator (ea)
Nam-won	35
Seo-san	6

In the case of Nam-won, there are 35ea of regulators because Nam-won sewerage service district is composed of a combined sewer and sanitary sewer system. In the case of Seo-san, there are 6ea of regulators caused by imperfect sanitary sewer construction in spite of the fact that Seo-san sewerage service district is composed only of a sanitary sewer system.

Table 4 shows the amount of overflows and pollution mass load at the regulator of the two cities.

Table 4: The amount of overflow and pollution mass load at the regulator.

		Overflows (m^3/d)	Mass load (kg/d, BOD basis)
Under dry weather	Nam-won	6,988	0.03
	Seo-san	4,410	63.8
Under wet weather	Nam-won	33,886	559.1
	Seo-san	18,848	651.1

During dry weather, the amount of overflows of Nam-won and Seo-san are 6,988m^3/d and 4,410m^3/d respectively and the pollution mass load is 0.03kg/d and 63.8kg/d, respectively. During wet weather, the amount of overflows of Nam-won and Seo-san are 33,886m^3/d and 18,848m^3/d respectively. And the pollution mass load is 559.1kg/d and 651.1kg/d, respectively. As a result of those surveys, we can tell that a significant amount of mass load is discharged into the public water basin during wet weather compared with during dry weather. And those things have a considerable effect on water pollution.

2.2.2 Interceptor sewer/sanitary sewer

Both interceptor sewers and sanitary sewers are designed to collect sewage generated in municipalities through both private sewer laterals and sewer laterals and transport it safely to the POTW. The water quality of influent into a POTW is increasing due to intensive investment in both installing sewage treatment plant and rehabilitation of the sewer system. But relatively low water quality of influent compared with designed water quality still have become a problem of inefficient operation due to problems (e.g. *crack, incursion of root, backing up of river water*) of sewer buried in a river bank or river bed.

Table 5 shows the status of interceptor sewer and sanitary sewer of Nam-won and Seo-san.

Table 5: The status of interceptor sewer/sanitary sewer in the two cities.

	Buried in land (m)			Buried in river-bed (m)		
	Total	Gravity sewer	Force sewer	Total	Gravity sewer	Force sewer
Nam-won	17,488	16,631	857	53,999	53,999	–
Seo-san	37,118	33,811	3,307	25,836	25,836	–

We also surveyed conditions of internal pipeline and estimated the amount of inflow/infiltration (I/I) entering an interceptor sewer through CCTV, flow monitoring and water quality analysis. Table 6 represents the amount of I/I of each interceptor sewer in Nam-won and Seo-san and figures 3 and 4 show pictures of the internal interceptor sewer of the two cities, respectively.

Table 6: The amount of I/I of each interceptor sewer in Nam-won and Seo-san.

		I/I amount (m^3/d) during dry weather	I/I amount (m^3/d) during wet weather
Nam-won	Yo river	7,089	17,177
	Okryul river	688	1,013
	Gwang-chi river	2,640	5,176
	Juchon river	2,121	3,410
	Wonchun river	1,084	1,479
	Go-juk river	241	984
	Baek-am river	723	1,367
	Gal-chi river	822	928
	Total	15,408	31,534
Seo-san	Chung-chi river	7,408	27,105
	Dun-dang river	905	1,383
	Hae-mi river	4,310	9,425
	Total	12,623	37,913

As shown in table 6 and figures 3 and 4, we can see that a lot of I/I entered the interceptor sewer. As a result of entering I/I, diluted sewage which is collected from private sewer laterals running an interceptor sewer/sanitary sewer and the amount exceeding the designed capacity of the POTW are discussed.

Figure 3: The pictures of internal interceptor sewer conditions in Nam-won.

Figure 4: The pictures of internal interceptor sewer conditions in Seo-san.

2.3 Sewage treatment step

In the case of a combined sewerage system, although design sewage flow during wet weather should enter the POTW and a part of those things which is peak day flow should be ordinarily treated through the main treatment process, the other should be discharged after treating through a simple treatment process (e.g. *settling and disinfection*) in principle, only peak day flow enters and is treated as controlling inflow gate as well as sewage exceeding design capacity of the POTW is discharged without any treatment because of insufficient POTW capacity. After all, the POTW cannot help being illegally operated during wet weather.

In the case of a sanitary sewerage system, despite the fact that all sewage entering the POTW should be treated, there is practically no POTW which has sufficient capacity as well as sewage during dry weather which is below peak day flow is only disposed to meet effluent regulations.

Table 7 shows the data of overflows at a manhole and primary settle tank during wet weather.

Figure 5 shows the precipitation effect on treatment capacity of the POTW in Nam-won and Seo-san.

As can be seen in Figure 5, in most cases the influent flow exceeds the capacity of the POTW (design capacity: Nam-won; 50,000m^3, Seo-san; 40,000m^3) during wet weather. Especially, in the case of Seo-san, despite the construction of the sanitary sewer system, the capacity of the POTW is exceeded when every precipitation occurs. We also reviewed seasonal maximum treatment ability of the POTW As a result, the nitrogen treatment ability is reduced in accordance with the temperature drops in winter, whereas the treatment capacity of reactor is increased according to the increased efficiency of biological treatment as the temperature increases. Thus it is necessary to properly control the influent flow which is considered the treatment ability of a unit process. Figure 6 shows how to calculate the seasonal maximum treatment ability.

Table 7: The overflows and mass load at a manhole and primary settle tank.

		Manhole in front of STP	Primary settle tank
Nam-won	Overflows (m^3/d)	3,841.5	27,782
	Mass load (BOD, kg/d)	167.5	1,803
Seo-san	Overflows (m^3/d)	–	17,552
	Mass load (BOD, kg/d)	–	631.8

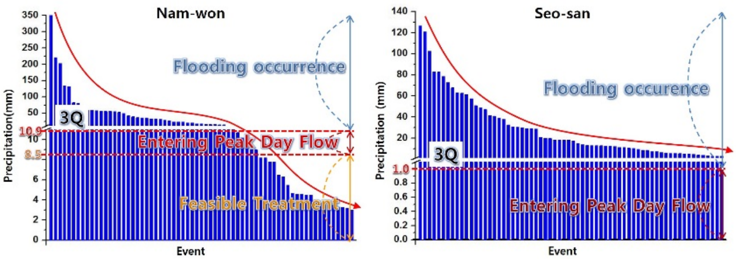

Figure 5: Precipitation effect on POTW treatment capacity.

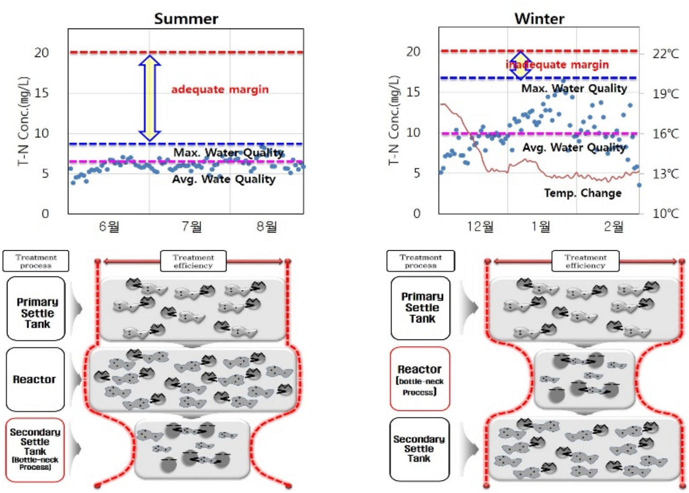

Figure 6: Review of seasonal maximum treatment ability in Seo-san.

3 Measure of sewerage management during wet weather

3.1 Collection step

Due to denial of householder and other critical issues caused by land occupation rights, it is inevitable that imperfectly constructed houses remain during implementation of separated sewer system. The measures for an imperfectly constructed house were given as follows.

A: Questionnaire and agreement for a project of a separated sewer system
In accordance with Korean sewage law, private sewer laterals are categorised into a private sewer system, and the building owners are responsible for installation of the private sewer laterals. The sewage law also notes that the government can financially and technically support the installation and maintenance of the sewer system. In principal, a land owner should cooperate with all activities associated with improvement of a sewer system. Although a questionnaire and agreement of the owners is not required, it is recommended obtaining the agreement in order to reduce conflict between government and the owners.

B: Installation of an individual sewage system
In Korea, the owners who deny installation of a separate sewer system should prepare their own private sewer facility to prevent the sewer reaching public surface water. The regulation also contributes to reduction of sewer generation and to block overflows during strong precipitation. Eventually, the load of WWTP was reduced.

C: Mitigation measure of I/I in lateral
In this study, we established mitigation measure of I/I in lateral. In Korea, sewer projects have been focused on the extension of sewer facilities. Therefore, a large part of the sewer system should be replaced owing to deterioration. Up to now, maintenance of the sewer system has been performed properly because of financial issues and political preference. The future sewer policy should be shifted from new installation to maintenance of current facilities to prevent critical issues (e.g. *groundwater intrusion, land subsidence*). A reliable subsidy for the maintenance can be a proper measure in the future.

D: Consideration of inevitable RDII
When designing the sewerage system, if both economic feasibility and environment effect are secured through the treatment of untreated wastewater, RDII should be included in the design capacity within the sewer spare capacity considering regional conditions based on RDII monitoring data. It can make overflows and discharge of untreated wastewater minimal.

3.2 Transportation step

3.2.1 Regulator

A regulator controlling the load is not managed properly. Furthermore, a reliable regulator cannot be calculated under the present estimation system. In this study, we set short-, mid- and, long-term measures for problems which occur because of an unsuitable regulator.

A: Short-term measures

All operated regulators were inspected to find individual defects and systematic malfunctions. The observed problems were recorded in the managing system for regulators. Height of weirs were also adjusted to increase the amount of sewer collection. A gate for the prevention of backflow was constructed in front of the regulators located near the river, since reverse flow was frequently observed in the regulators. Regulators in a site planned for development and in an old residential area were relocated in the upper region of the river to optimise coverage of the regulator.

B: Mid-term measures

Regulation and policy were reformed based on the DB of overflows (e.g. *frequency, amount*), and the purpose of the amendment was to determine prior site. CCTV and water gauge were equipped in the regulator of the chosen sites to control overflows and to remove sediment. Consequently, the mid-term measures focused on mitigation of initial load.

C: Long-term measures

In long-term measures, all regulators were integrated into one managing system. In order to control overflows and load of regulators, criteria of CSOs which can consider Korean weather and sewer system will be established.

3.2.2 Interceptor sewer/sanitary sewer

In Korea, lateral sewers have been maintained without an integrated plan and analysis. Interceptor sewers have been repaired based on partial inspection and primary information (e.g. *pipe type, construction year*), although intensive inspection was required in the planning step. Inlet of I/I is a critical issue in sewer management. In this study, several measures are suggested as given below.

A: Intensive inspection

To find sites where repair or change of pipe is required, CCTV inspection was performed. The inspection sites were determined using primary data of the sewer system (e.g. *pipe type, construction year, water flow and quality*).

B: Establishment of plan for sewer transport

During repair of a separated sewer system, the generated sewer should be transported into POTW without any leakage. In particular, influent interceptors where a separated sewer system was already constructed can be available as sanitary sewer, after dismantle of regulator and repair of manhole. Overall, the master plan on sewer maintenance should be accompanied prior to the POTW.

C: Maintenance of manholes

Manholes installed in river should be integrated manholes. The manhole where the water intrusion was found had to be repaired using reinforcement of internal and external structure to enhance water tightness.

3.3 Sewage treatment step

The ideal operation of a POTW connected to a combined sewer system is that all sewer (3Q) passes through a main stream (1Q) and auxiliary facility (2Q). Most POTW do not have a primary settle tank so the operation principle of the POTW should be pollutant loads and untreated sewer obtained from regular monitoring.

In the case of a POTW connected to a separate sewer system, an aerobic tank can be operated based on the maximum design loads during the rainy season. In general, an acceptable load of the POTW is practically determined with the sludge interface of a secondary settle tank.

The priority in this study was the optimisation of current facilities and system. The optimisation was performed with monitoring and estimation by external experts. The main focus for a combined sewer system was to reduce untreated effluent during precipitation through a simplified treatment system. The improvement of the separate sewer system was mainly focused on minimisation of I/I. A sewage storage tank was installed in combination with the separate sewer system to handle shock loads during wet weather.

4 Future plan

4.1 Amendment of related law

According to the current Sewerage Act, it is necessary to reflect additionally on related laws in order to enhance the effect on sewerage management during wet weather since a sufficient legal basis is not defined. Therefore, we are planning to amend the Sewerage Act and directives to give legal liability on sewerage operation.

4.2 Sustainable protection of water through enlargement of guidelines

The guidelines derived through exemplary sewerage works will be spread out to all POTW (over $500m^3/d$) in Korea in order to minimize the problem regarding sewerage during wet weather. Finally, we will protect our water resources sustainably.

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