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RESEARCH STUDY FOR COMPACT COMBINED SEWER SYSTEM IMPROVEMENT TECHNOLOGY AT DIVERSION CHAMBERS

PRACE BADAWCZE NAD ULEPSZENIEM TECHNOLOGII OCZYSZCZANIA ŚCIEKÓW ZE ZWARTYCH SYSTEMÓW KANALIZACJI OGÓLNOSPŁAWNEJ

In Japan, a combined sewer system that collects sanitary sewage and stormwater runoff in a single pipe is adopted in cities that have developed sewerage since old times. In the combined sewer system area, the effect on ecosystem of public water bodies, hygienic safety, and securing fine landscapes are points of concern since untreated wastewater consisting of wastewater and storm water overflows from intercepting sewers and is discharged to public water bodies in the wet weather.
Recently, in Japan, improvement measures for the combined sewer system are being taken while focusing on three items, namely, reduction of pollutant load, security for public health, and reduction of debris. However, there are many diversion chambers at the combined sewer system in the cities, and construction of storage facilities is a problem due to difficulty of securing area and crowded existing underground facilities.
In this method, a rapid filtration system technology that can be installed at small sites is adopted to remove BOD from combined sewer overflow. To use the method for sites where construct storage facilities are hardly constructed because of limitation of area, combined sewer system improvement measures will be advanced.
In this report, an experiment result of BOD removal rate by this method, and a case study result compared to a storage method are introduced.

1. Background and Purpose of Research

The Bureau of Sewerage, Tokyo Metropolitan Government is actively promoting the combined sewer system improvement measures and planning to ensure the storage volume of approximately 1.7 million m3 by the end of the fiscal year 2023 in order to reduce pollutant loads from stormwater outlets. However, since most of the stormwater outlets of natural drainage area are located in an urban area, it is difficult to install reservoir facilities due to the limited availability of space and the existing congested underground facilities, causing challenges for the project.

This research was carried out for the purpose of developing a unit of compact and simplified treatment system (hereafter called the "high-rate filtration manhole") that can be installed at roads etc. near the natural drainage outlets and has an appropriate pollutant removal efficiency (BOD removal rate of 50% or more).

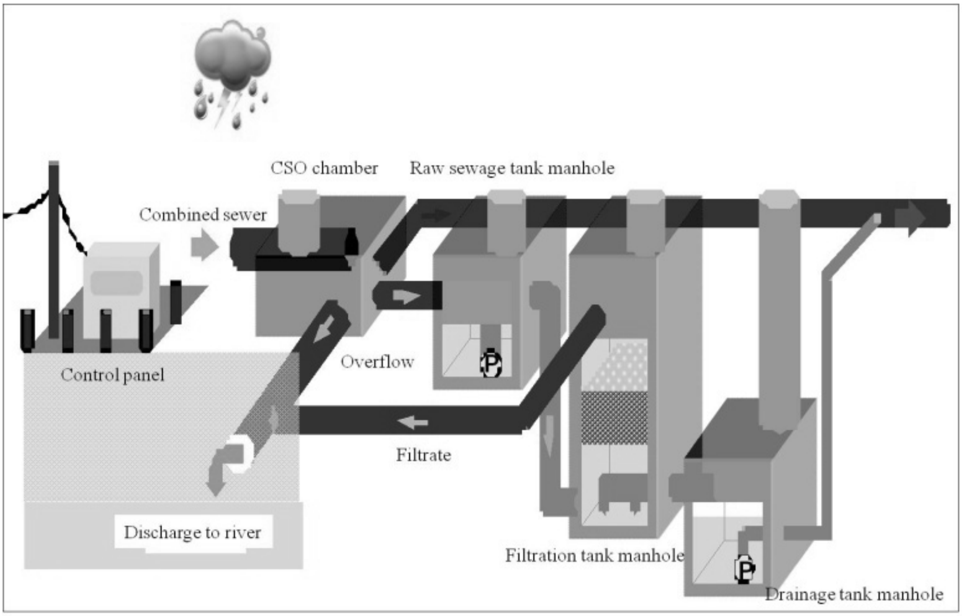

Fig. 1. Overview of the compact and simplified treatment system

2. Research Agendas

Following are the technical agendas for this research.

2.1. Area minimization

1) Since most of the stormwater outlets are installed at narrow community roads with congested underground facilities, the system should be compact and possibly constructed in a short period under such conditions.
2) Since the size and shape vary in each stormwater overflow tank and the positional relationship of the system with an intake or discharge point and an outlet point of wash drainage water (intercepting sewer) and also the limitations on the site area and construction methods are different, the system should be able to meet various requirements.

2.2. Treatment performance

Even if the raw sewage of interest is the untreated sewage that has overflown from a stormwater outlet in a natural drainage area different from the conventional technology, the technology is required to meet the target pollution removal efficiency.

2.3. Operation and maintenance

Assuming that the multiple systems are constructed under the ground, dotted all over the area, and checking the treatment status and conducting inspection and maintenance work is difficult, the technology is required to ensure efficient operation and maintenance.

3. Overview of Technologies

3.1. Overview of high-rate filtration technology

3.1.1. Filter media

Special floating filter media (Photo 1) are characterized by the windmill shape with large convexes and fine particles (7.5 mm x 7.5 mm x 4 mm). This media is advantageous in trapping SS due to the high porosity, and the duration of filtration is relatively long. Voids are created between the filter media by the downward countercurrent during backwash cycle, and the SS trapped between the convex surface can be easily washed out. This filtration process does not require coagulants to be added, and it is also effective in removing BOD by the fine particles (However, soluble BOD cannot be removed).

Photo 1. Special floating filter media

3.1.2. System operation and water flow

The system operation and water flow are shown in Figure 2. As shown in "I. . Filtration Start", the water levels of the pressure control tank and the filter bed are the same immediately after the start of filtration. The filtrate flows out of the filtration tank at the same rate as the raw sewage flows into the pressure control water channel. As the filter media are clogged, the water level of the inflow pressure control water channel rises as shown in "II.. Filtration in Progress". When the water level reaches the predefined level (400mm to 800 mm), the process continues to "III. . Backwash under Rain Conditions" and the system starts washing the filter media. During "III. . Backwash under Rain Conditions", the wash drain valve at the bottom of the tank should be opened to wash the filter media. After rainfall, the filtermedia is completely washed and substituted with the secondary effluent as shown in "IV.. Wash after Rainfall" and the system waits for the next rainfall.

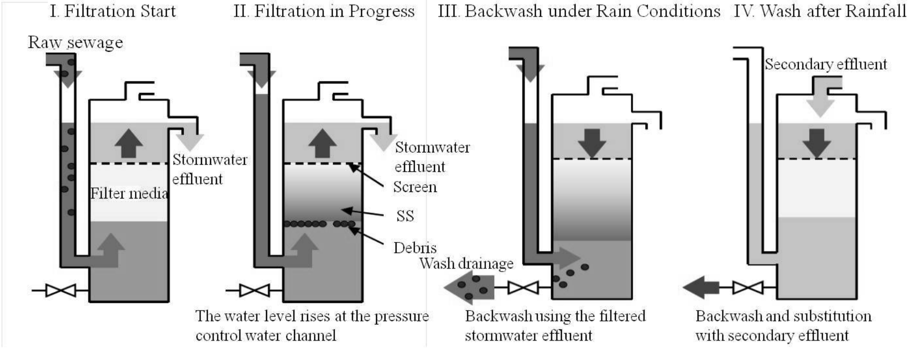

Figure 2. System operation and water flow

3.2. Installation position and pollutant load reduction

The high-rate filtration manhole system is applied between the stormwater overflow tank and the stormwater outlet to river, etc. The purpose of this system is to reduce the effluent pollutant load by treating the part of untreated sewage that has overflown from the stormwater overflow tank.

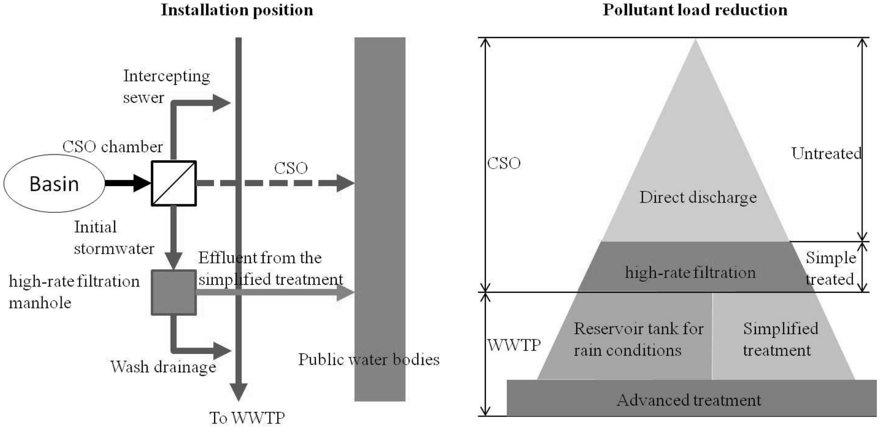

Fig. 3. Overview of installation position and pollutant load reduction

4. Research Method and Experimental Conditions

4.1. Experimental system

In the verification test of this research, we assumed the actual facility size and structure to design and manufacture the filtration system with a height of 5 m and the unitized wash drain valve as shown in Photo 2. Then, we installed the filtration system at the Pump Station of Bureau of Sewerage, Tokyo Metropolitan Government. A window is installed in the experimental plant so that we can see the part of high-rate filtration manhole to check the filter media, and a temporal reservoir pit is also provided to return the wash water and backwash drainage water. The pump sending raw sewage to the filtration system was installed approximately 30 m away from the intake point.

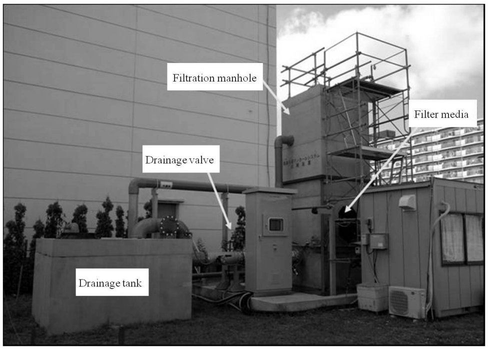

Photo 2. External view of experimental system

4.2. Experimental conditions

4.2.1. Operation at standard conditions

We carried out this experiment to confirm if the contaminant removal efficiency of this system is equivalent to that of the high-rate filtering system with preliminary sedimentation tank under rain conditions. We used the same filtration rate and filter media thickness as those used in actual operations of high-rate filtration systems that were implemented in various regions after SPIRIT21[*1].

Filtering rate: 1,000 m/day
Filter media thickness: 800 mm

*1 SPIRIT21

To develop appropriate technologies for sewage works, MLIT initiated a project called Sewage Project, Integrated and Revolutionary Technology for the 21st Century, or SPIRIT 21. As the first theme, the project conducted research during 2002-05 of CSO treatment and instrumentation.

4.2.2. Experiments by changing the filter media thickness and filtering rate

We carried out this experiment to confirm the relationship between the contaminant removal efficiency and the filtration rate and filter medium thickness. When changing the filter media thickness, we did not change the top screen position, but changed the quantity of filter media to be filled.

Filtering rate: 500, 700, 1000, 1100 m/day

Filter media thickness: 400, 600, 800 mm

4.3. Water quality analysis

We also carried out water quality analysis to check if the high-rate filtration manhole system is achieving the predefined contaminant removal efficiency. In general, water quality surveys were conducted under rain conditions; however, some surveys were conducted under no rain conditions in order to complement the experimental data.

Tab. 1. Water quality analysis items and their quantities

Analysis item	Rain condition	No rain conditions
SS	20	3
BOD	20	3

* Unit: Number of samples per 1 RUN

4.4. Calculation method for the removal rate

The removal efficiency of BOD and SS for the high-rate filtering manhole system is evaluated as a removal rate according to the evaluation in SPIRIT21. The removal rate is calculated from the ratio of influent (raw sewage) load and effluent (treated sewage) per run. The concentrations measured at each sampling point are connected with a line, and the integrated areas under the curves are compared between the raw sewage and the filtrate to obtain the removal rate as shown in Figure 4.

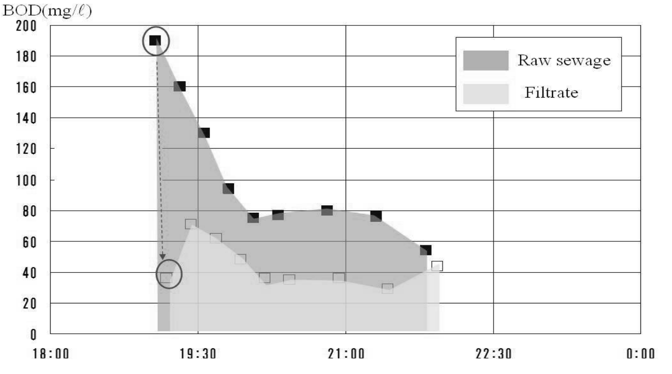

Fig. 4. How to obtain the removal rate

5. Research Results

5.1. Removal efficiency of BOD

The relationship between the influent BOD load and the effluent BOD load is shown in Figure 5. The BOD removal rate lies between 36% and 70%, and the average value is 53%. For the filter media thickness of 400 mm and 600 mm, the BOD removal rate is approximately 50% regardless of the size of influent load, and for the filter media thickness of 800 mm, the BOD removal rate varies widely. This variation is due to the influence of the filtering rate rather than the influence of the influent load.

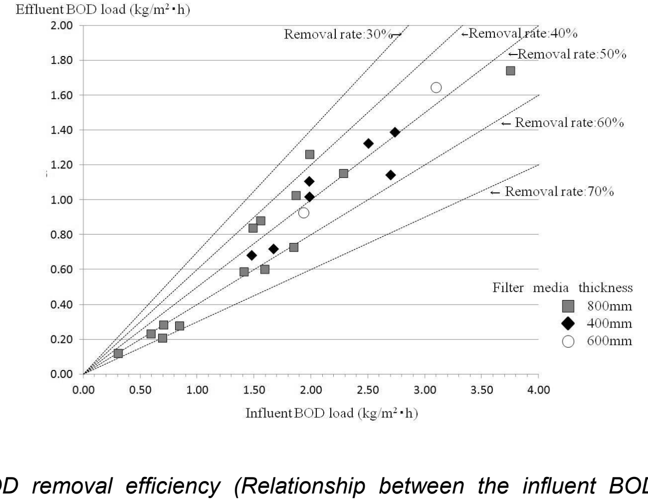

Fig. 5. BOD removal efficiency (Relationship between the influent BOD load and the effluent BOD load)

5.2. Removal efficiency of SS

The relationship between the influent SS load and the effluent SS load is shown in Figure 6. The SS removal rate lies between 56% and 83%, and the average value is 68%. For the filter media thickness of 400 mm and 600 mm, the SS removal rate is approximately 60% regardless of the size of influent load, and for the filter media thickness of 800 mm, the SS removal rate varies widely. Similar to BOD, this variation is due to the influence of the filtering rate rather than the influence of the influent load.

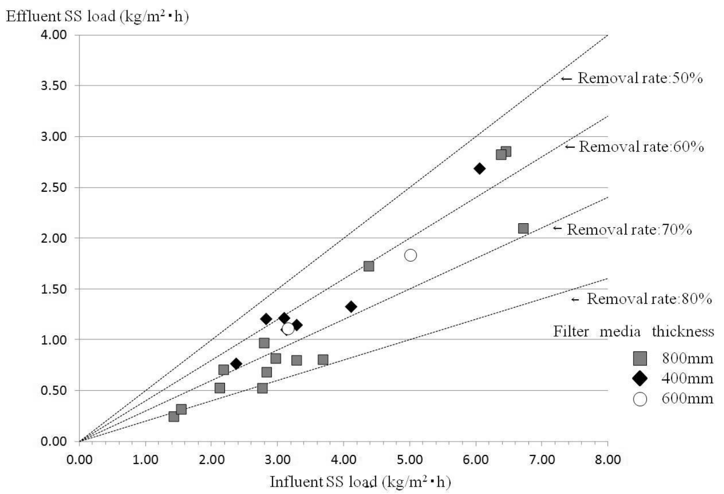

Fig. 6. SS removal efficiency (Relationship between the influent SS load and the effluent SS load)

5.3. Summary of the removal efficiency

We installed an experimental system of high-rate filtration manhole at the S Pump Station of Bureau of Sewerage, Tokyo Metropolitan Government, and performed a total of 23 treatment experiments under rain conditions during the period between May 2012 and January 2013. The results show that the BOD removal rates are about 50% and the SS removal rates are about 60% or more as shown in Table 2.

Tab. 2. Removal efficiency of BOD and SS

Filter media thickness (mm)	Filtering rate (m/day)	BOD removal efficiency (%)	SS removal efficiency (%)
800	507	60.6 - 70.1%	75.1 - 82.7%
		67.3%	80.7%
	727	59.8 - 60.9%	75.6 - 79.3%
		60.3%	77.2%
	988	36.6 - 62.2%	55.7 - 78.1%
		54.6%	71.2%
	1058	43.5 - 53.6%	55.7 - 68.7%
		47.1%	60.3%
	Overall	36.6 - 70.1%	55.7 - 82.7%
		56.4%	71.8%
400	503 - 1043	44.2 - 57.6%	55.6 - 67.7%
		52.7%	63.5%
600	507 - 992	46.9 - 52.1%	63.4 - 64.8%
		47.6%	63.6%

* The bottom row of the removal efficiencies shows the average value (time-weighted average).

6. Application of this Technology

The following effects should be taken into account in addition to the quantitative estimates of improvement effects for the combined system (effluent pollutant loads and the number of times untreated sewage is discharged) when a high-rate filtration manhole is implemented.

6.1. Visual improvements

The visual states of the raw sewage and filtrate samples are shown in Photo 3.

With a visual improvement in water flowing out of a stormwater outlet during rainfall, the residents of Tokyo can actually feel the benefit of the combined sewer system improvement project, which can help gain an understating of the projects by the Bureau of Sewerage.

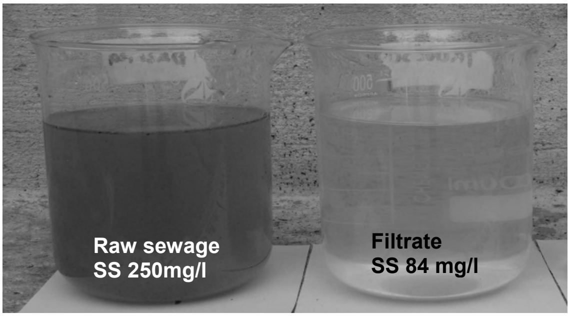

Photo 3. Raw sewage and filtrate

6.2. Emergency application in water treatment when the operation of the water reclamation center is stopped due to a disaster

If a high-rate filtration manhole is installed near the stormwater outlet, it can serve as an emergency sewage treatment facility when the water reclamation center is stopped due to a disaster, and the filtrate can be discharged to public water bodies after disinfection.. If we can unitize the whole treatment system including filter media, etc. and easily install, remove, and transport the system in the future development, it would be possible to carry out the simplified sewage treatment at the center by collecting the treatment units from the high-rate filtration manholes that are installed at different locations.

6.3. Implementation of the preliminary treatment process such as screening, etc. to increase the removal rate

Since the high-rate filtration manhole is designed to be installed at the stormwater outlet in natural drainage areas, it is difficult to include a preliminary treatment process such as screening, etc. with the current technology. If we can introduce such preliminary treatment and increase the BOD removal rate up to 90%, it would be possible to achieve an effluent pollutant load equivalent to that of a distributary channel with the filtration area of 15 m2 per 5 ha. If we can achieve a BOD removal rate of up to 90%, the application of high-rate filtering manhole would become widespread.

7. Conclusion

In this research, we obtained the BOD and SS removal rates achieved by a high-rate filtration manhole system having the size of an actual facility, and also performed preliminary calculation on the improvement effect of the combined sewer system when it is installed at the stormwater outlet.

- We confirmed that the target BOD removal rate of 50% or more can be achieved.
- We also confirmed that some improvements on the combined sewer system can be expected by installing the system at the stormwater outlet.

In the future, we are planning to conduct the study on an actual system installed at a stormwater outlet, and also a combination of the system with a reservoir tank, etc. for a widespread use by suggesting a reasonable application method of the high-rate filtration manhole system.

Acknowledgement

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