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RESEARCH ON THE SEWERAGE TREATMENT FACILITIES WHICH ARE APPLICABLE TO THE SMALL-SCALE VILLAGE AREA BY NEW DEVELOPMENT METHOD

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In Japan, the prevalence rate of sanitary sewage treatment in terms of population has reached 88.1 % by 2013. But in case of municipalities, whose populations are less than 50000, the prevalence rate is 74.4% and in such regions the rapid construction of sewerage system is strongly needed to improve the quality of the source of water supply and to protect water environment. On the other hand, such municipalities have usually faced financial difficulties and rapid population decrease. So, they tend to hesitate to construct sewage systems because common sewerage system is expensive. In these surroundings, Ministry of Land, Infrastructure, Transport and Tourism take initiative in researching and developing new construction techniques of sewage systems toward such regions, and we call them “extremely small-scaled bioreactor” in Japan. These techniques are packaged systems of sewage disposal and the applications of facilities which are generally used commercially. Therefore, we can expect the reduction of construction cost and the abbreviation of construction period. Also, they can be used flexibly, for example, if the facility is not needed in one area because of the population decrease, then it can be moved to another area where it is needed. Social experiments concerning “extremely small-scaled bioreactor” have been done in five municipalities in Japan. In this report, we mainly focus on the evaluation results of “extremely small-scaled bioreactor -contact oxidation type. Evaluation of the social experiment was conducted in terms of some points. There is following, construction cost, maintenance cost, construction period, treatment performance, sludge properties, improved living environment, and participation of residents. Presently, these results are summarized as technical standards and are utilized to promote the construction of sewerage system in the region where the quality improvement of the source of water supply and the protection of water environment are strongly needed.

1. Introduction

The overall sewage treatment rate has reached 88.1% in Japan. However, sewage treatment systems are not widely spread in rural areas, or even in some more densely populated areas. In particular, in municipalities whose population is less than 50000, the sewage treatment rate is only 74.4%, which is more than 10% lower than the overall rate. In such regions, the rapid construction of sewerage systems is strongly needed to improve the quality of the water supply and to protect the water environment. On the other hand, such municipalities often face financial difficulties and rapid population decrease and so tend to be hesitant to construct expensive sewerage systems. Therefore, the urgent review of each stage of planning, design, and construction on the basis of the current social situation such as rapid population decrease is required in order to implement new sewerage systems and solve issues associated with aging facilities. The Ministry of Land, Infrastructure, Transport and Tourism has taken the initiative in researching and developing a new "extremely small-scaled bioreactor" for such regions.

By verifying the performance and effect of a new sewerage system construction technique that can provide inexpensive, quick and agile construction using actual examples, we aim to apply this technique to the construction and renovation of sewerage systems across the country.

In this paper, we report the findings of a case study of an extremely small-scaled bioreactor (manufactured in a plant), implemented as a pilot study in Japan, during the initial operation (immediately after the start of service).

2. Overview of extremely small-scaled bioreactor (manufactured in plant)

An illustration of the treatment plant is shown in Figure 1. The extremely small-scaled bioreactor uses commercially available products and a packaged treatment facility as a sewage treatment plant to reduce the cost and construction period. Facilities no longer in use due to population decline can be transported to another location. Note that the main materials used are FRP and vinyl chloride; therefore, the durability is different from that using reinforced concrete and SUS.

The contact oxidation process applied in this experiment is a treatment process using a biofilm, which does not require return sludge and produces less excess sludge compared with the activated sludge process. However, the attached biomass cannot be voluntarily controlled, so it is difficult to support changes in operation conditions. This technology can be classified into two types: One with a sedimentation tank equivalent to a primary sedimentation tank and the other with a flow control tank instead of a sedimentation tank.

In order to reduce the cost, less automatic measuring equipment (used to collect information on the operation and water quality status) is installed in this technology. For this reason, it is difficult to control the operation quantitatively. Therefore, as a reference for the operation, it is desirable to observe and record qualitative information on the status inside the tanks, such as color, odor, and biofilm formation state, in addition to quantitative information obtained from the water quality measurements, such as transparency, scum, and sludge thickness. According to the circumstances, information to be recorded can be customized to each region or country.

At this point, the proven contact oxidation process and membrane separation process (manufactured in a plant for each case) and also new processes such as PMBR have been implemented as a pilot program for the treatment process of the extremely small-scaled bioreactor. Currently these processes are in service in five municipalities in Japan.

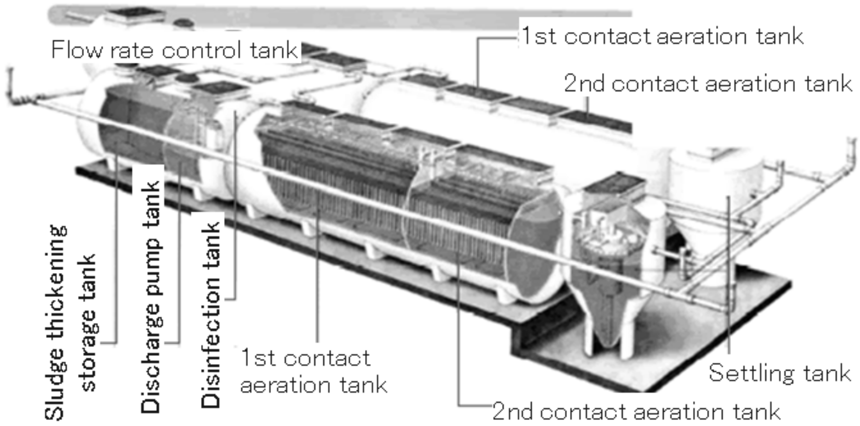

Fig. 1. Illustration of extremely small scale treatment facility

3. Overview of the city in the pilot study

In this paper, we report an example of a contact-oxidation-type bioreactor. An overview of the sewerage plan is shown in Table 1, and an overview of the treatment plant is shown in Figure 2. Tomamae set the fiscal year of 2015 as the target year for the completion of the sewerage plan and obtained the project approval. They have also started the sewerage project. The capacity of the treatment plant is designed to be 330m3/d in total. Currently, the construction of the first system with a capacity of 55m3/d and the second system with a capacity of 110m3/d has been completed. A contact oxidation process is used in the sewage treatment facility, and sewage flows into the contact aeration tank via the flow control tank. After being treated by contact oxidation using a carrier, the clean water separated in the settling tank is discharged to a river. The planned effluent quality is set to 15 mg/l for BOD and 40 mg/l for SS on the basis of the Japanese sewage effluent standard.

Tab. 1. Overview of sewerage plan

	Items		Planned value*
Sewerage plan	Target year		2015
	Sewer system		Separate
	Planned area (ha)		43
	Planned population (people)		990
Treatment plant	Treatment process		Contact oxidation process
	Treatment capacity (m3/d)	Total capacity	330
		Current capacity	165
	Target effluent quality (mg/l)	BOD	270→15
		SS	210→40

* Same values for overall plan and project plan

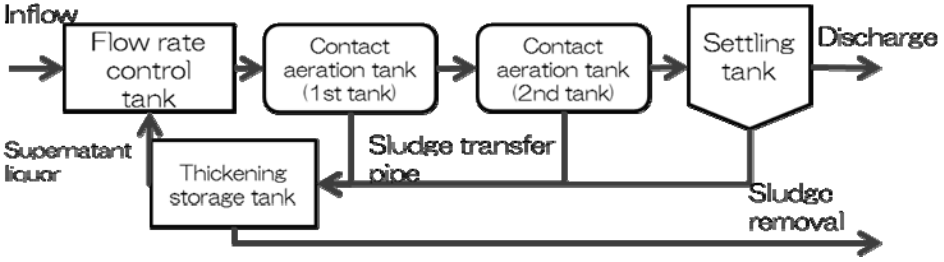

Fig. 2. Overview of treatment plant

4. Verification results and discussion

In this project, we verified the following items.

4.1. Construction cost and period

A comparison of construction costs and periods is shown in Figure 3. The new process, compared with the conventional process (oxidation ditch process) equivalent to the current capacity of 330m^3/d, resulted in a 53 % reduction in construction cost and a 75 % reduction in construction period.

This technology can reduce the construction cost significantly by manufacturing the facility in a plant to reduce the workload associated with on-site fabrication and by simplifying the specifications with less equipment and unitizing the facility design. Therefore, it is possible to reduce both the construction cost and period. The construction of the foundation is often influenced by the regional conditions. The cost of this new process includes the pile foundation construction (approximately 9% of the cost). In some cases, a spread foundation can be adopted depending on the soil conditions. If so, the cost reduction would be much greater. The conventional process (oxidation ditch process) requires 18 months to construct the facility, while the new process requires only about 4.5 months; therefore, the construction period can be greatly reduced. In addition, the construction period of 4.5 months is sufficient to construct a facility within one year even in areas with heavy snow, where construction is halted during winter, and the occurrence of cold joints, as seen in the construction by the conventional process, can be avoided.

Tab. 2. Estimate of construction cost

		New method	**Conventional method**
The water treatment method		Contact oxidation process	Oxidation ditch process
Construction cost (1 million yen)	**Foundation**	120（60×2units)	159
	Structures		101
	machinery equipment	166（83×2units）	220
	electrical equipment		74
	Total	286	554
Ratio of initial cost		0.52	1.00
Update construction cost (1 million yen)	**machinery equipment**	249（83×3units）	440
	electrical equipment		148
	Total	249	588
Total construction cost(for 50years)		535	1,142
Ratio of construction cost by new method to conventional method		0.47	1.00

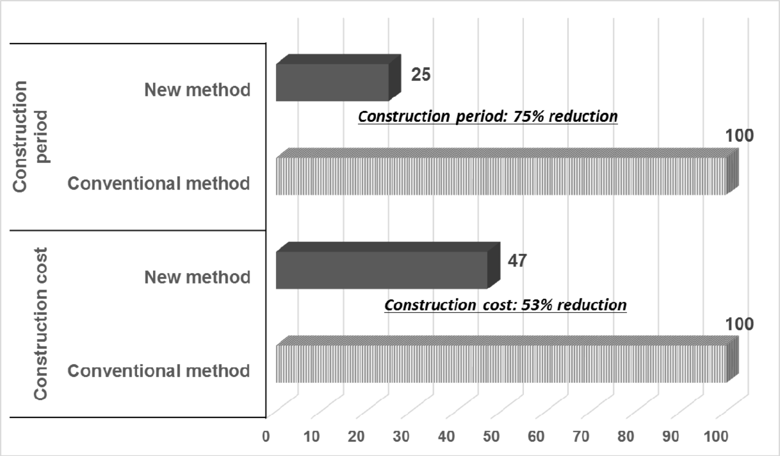

Fig. 3. Comparison of construction costs and periods

4.2. Operation and maintenance cost

Because not enough time has passed since the start of operation, we have not calculated the operation and maintenance cost for the steady operation, where the inflow rate is close to the current capacity. As a reference, the operation and maintenance cost for a 55m^3/d equivalent is 3.57 million yen/year. For comparison, the operation and maintenance cost for the same-scale conventional process used in Japan (including sludge processing from condensation to direct dewatering) is calculated to be 7.42 million yen/year. The sewage volume is currently low, and the cost per a certain water quantity is assumed to be relatively high. However, the cost reduction effect increases as the inflow increases.

4.3. Treatment performance

4.3.1. Inflow rate

The inflow rate is shown in Figure 4. The average inflow rate was 22.0m^3/d (inflow ratio of 40%) in a system with a capacity of 55m^3/d.

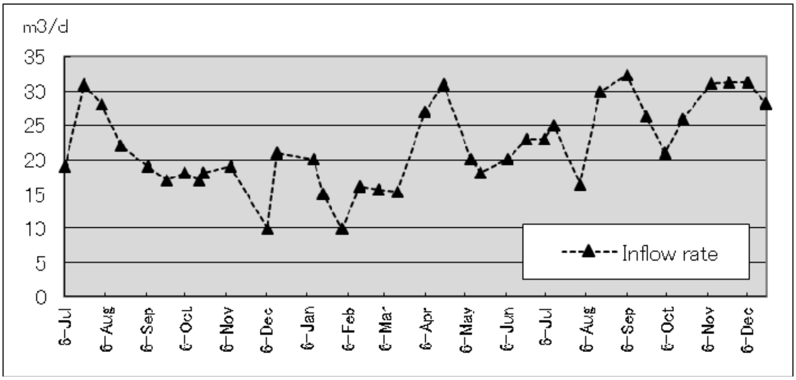

Fig. 4. Inflow rate (m^3/d)

4.3.2. Ambient temperature and water temperature

The ambient temperature and water temperature are shown in Figure 5. Since the demonstration site is located in an extremely cold area, the facility is installed underground for heat insulation purposes. However, it is still affected by the harsh environment, including large seasonal variations in ambient temperature and sub-freezing average daytime temperatures during the winter months. For this reason, the water temperature variation is also relatively large throughout the year. From the lowest observed temperature, it is necessary to consider the influence of temperature on the biological treatment.

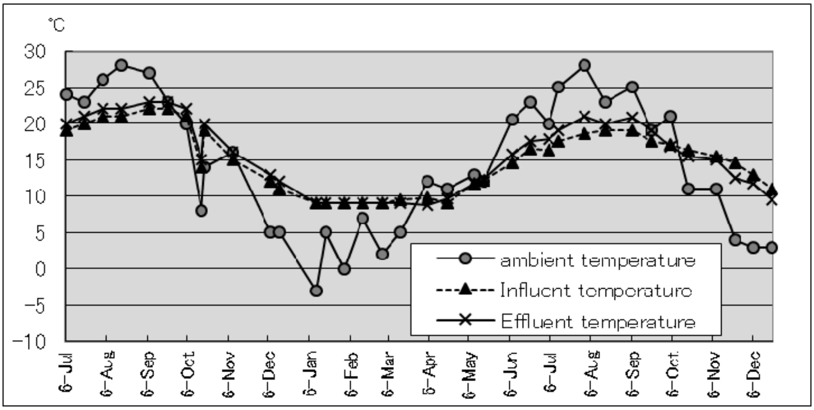

Fig. 5. Ambient temperature and water temperature (℃)

4.3.3. pH

The pH is shown in Figure 6. Both influent and effluent showed neutral pH and good stable condition. However, the effluent pH showed a tendency to be lower than the influent pH. Since the number of hydrogen ions increases due to the nitrification reaction, there is a necessity to observe the pH condition over time by measuring NH 4 -N as required.

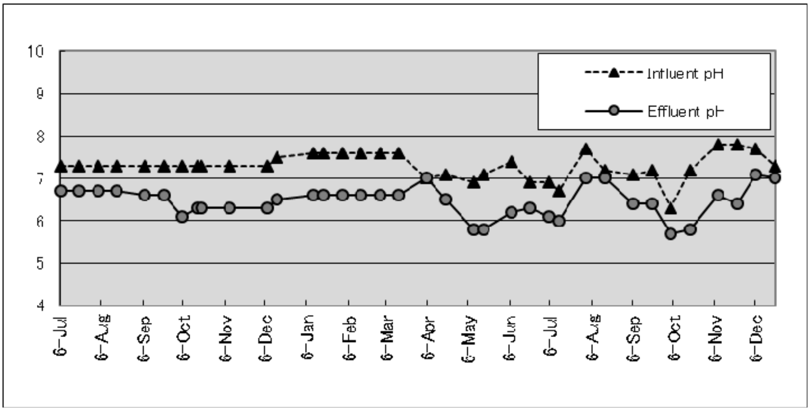

Fig. 6. pH

4.3.4. Effluent BOD and effluent SS

The effluent BOD is shown in Figure 7, and the effluent SS is shown in Figure 8. The effluent quality was better than the quality that of before the sludge removal in June. In addition, both BOD and SS concentrations were below the standard values for all times measured including the periods with the lowest water temperature. We confirmed that there is variation in the treatment status. This variation is considered to be due to the influence of fluctuation in the inflow rate. It is also necessary to appropriately control the airflow volume to accommodate the increase in sewage quantity and the inflow rate fluctuation in the future.

The contact oxidation process does not efficiently flocculate microorganisms that are intermittently peeled off from the biofilm. Hence, the effluent tends to show a white turbidity and a lower transparency than that of the activated sludge process. Particularly in a period with low water temperature, fine SS adhesion to the biofilm and the removal rate are reduced, causing the SS concentration to increase and the effluent to become less transparent. Therefore, it may be necessary to install a rapid sand filter after the settling tank if good transparency is required.

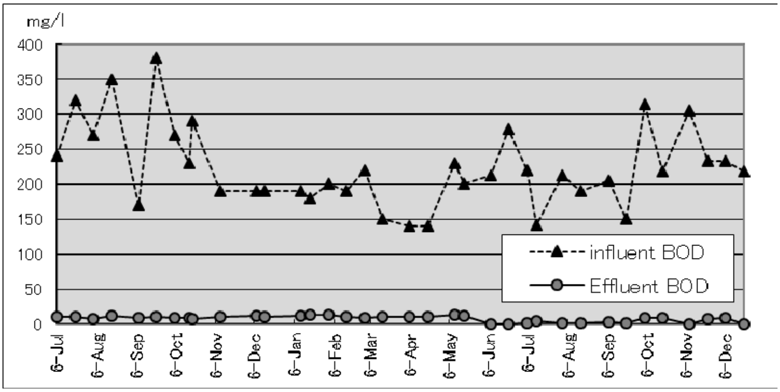

Fig. 7. *Influent BOD and effluent BOD (mg/l)*

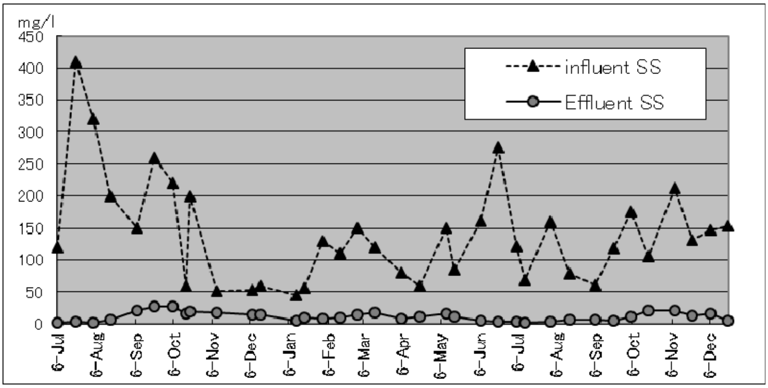

Fig. 8. *Influent SS and effluent SS*

4.3.5. E. coli counts

All E. coli counts in the effluent during the verification period were not detectable (ND).

4.4. Sludge properties

The sludge removal status is shown in Table 2. Since the facility is operated using highly concentrated sludge from the start of operation, the concentration of the removed sludge is very high. In the future, it is necessary to seek an appropriate timing for sludge removal and also determine the sludge properties while observing the SS concentration in the effluent. Although the settling properties cannot be confirmed for the steady operation, it is believed that the time required to reach the stable condition as the retention time is relatively long.

Tab. 3. Sludge removal status

Item		**Results**		**Note**
		13-Dec	**26-Apr**	
Before thickening	**Water content**	—	—	
	Settling property	—	—	
Removed sludge	**Water content**	97%	98%	Planned value 98%
	SV30	100%	100%	
	SV120	100%	100%	

4.5. Odor

Measurement items of odor and their measurement examples during sludge removal are shown in Table 4. This facility satisfies the Japanese regulatory standard of the Offensive Odor Control Act. However, we also set an original target, as shown in Table 4, for odor that is often generated in sewage treatment facilities. In some cases, the hydrogen sulfide concentration was slightly above this target at the site boundary during sludge removal. It is possible to reduce the hydrogen sulfide concentration by installing a wall at the sludge outlet port to narrow the opening, adopting an exhaust system during sludge removal, and arranging the working time.

Tab. 4. Measurement items of odor and their measurement examples during sludge removal

3-Dec	**Target value**	**Nomal**		**During sludge removal**	
	（ppm）	**In the facility**	**At site boundary**	**In the facility**	**At site boundary**
Ammonia	2	Not detected	Not detected	Not detected	Not detected
Hydrogen sulfide	0.06	〃	〃	0.039	0.076

Methylmercaptan	0.004	〃	〃	Not detected	Not detected
Methyl sulfide	0.05	〃	〃	〃	〃
Methyl disulfide	0.03	〃	〃	〃	〃
Trimethylamine	0.02	〃	〃	〃	〃

4.6. Improvements in living environment with the introduction of technology

As of the end of December 2011, 1 combined septic tank (treating all domestic wastewater), 3 single septic tanks (treating wastewater from toilets only), and 93 pit toilets have been replaced with a public sewerage system. With these improvements in the living environment, we could reduce the discharge of gray water and ensure environmental sanitation.

4.7. Community participation

We held a community meeting and adopted a Patlite failure report system for residents to detect failures and take action with support from the community. In practice, it took two and a half hours from when the Patlite was lit to when the failure was actually reported. In order to shorten the time to report the failure, we need to further increase awareness among residents living in the vicinity and engage them in monitoring activities.

5. Result

The construction cost and period can be reduced significantly. (Construction cost: 49% reduction, construction period: 75% reduction)

We confirmed that the effluent quality satisfied the Japanese standard value (BOD: 15 mg/l, SS: 40 mg/l) throughout the verification period. The airflow volume needs to be controlled on the basis of the influent load condition, and sludge also needs to be removed regularly in order to maintain good water quality. Since the low pH in the effluent due to the nitrification process has been confirmed, there is a necessity to observe the pH condition over time by measuring NH_4-N as required.

Although the results satisfied the regulatory standard of the Offensive Odor Control Act, it is still necessary to take action to prevent odor (hydrogen sulfide) caused by sludge removal if the plant is surrounded by residential buildings.

Since the number of microorganisms cannot easily be increased in the contact oxidation process, it is difficult to enhance the treatment performance in a short period.

6. Conclusions

In the short-term projects undertaken in Japan, there are other generalized technologies on the sewer pipes. Since the current evaluation is conducted while the facility is in operation, we still need to observe the treatment performance over a longer time period. However, we could confirm that this technology can reduce the construction cost and period. In the future, we would like to facilitate further adaptation of this technology to address challenges regarding treatment performance and geographical characteristics. When the construction cost, effluent quality, site area, operation and maintenance are comprehensively evaluated, we believe that this technology can be advantageous to solve the problems in areas where no sludge treatment system has been implemented.