Study on Measures against Changes in Flowrate of Rainfall by the Membrane Bioreactor (MBR) System Equipped with Ceramic Flat Sheet Membranes (CFMs)

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Abstract

In medium and large-scale sewage water treatment plants, a combined sewer system is common. Under such a system, the efficiency to remove Suspended Solids (SS) and coliform groups tends to lower in the solids-liquid separation process at the final sedimentation tank when influent rainwater exceeds a specified level in rainy weather. In such cases, the market calls for effective measures of improvements. An introduction of the Membrane Bioreactor (MBR) is an effective measure for combined sewer systems. By this measure, during rainfall, (1) the reduction of the amount of water discharge by the simple water treatment process or water discharge without any treatment and (2) an improvement on the quality of the discharged water can be expected.

In this study, we immersed our Ceramic Flat sheet Membrane (CFM) units into the reaction tank of the Hanno City Purification Center and carried out a filtration flow rate variation operation linked to the effluent water volume. As a result of this verification test on the effect of improving running water quality, the MBR is applicable to the combined sewer system.

1 Preface

In order to promote the further introduction of the Membrane Bioreactor (MBR) system, it is anticipated to occur during the modification or expansion of sewage water treatment plants. In this connection, the issue of how to apply the MBR to the combined sewer system arose. Such a sewer system is common in medium and large-scale sewage water treatment plants in Japan.

This paper introduces the result of the verification test of MBR application to a combined sewer system at the Hanno City Purification Center, Saitama Prefecture. This Center partially adopts the combined sewer system.

2 Outline of Research and Development

2.1 Application

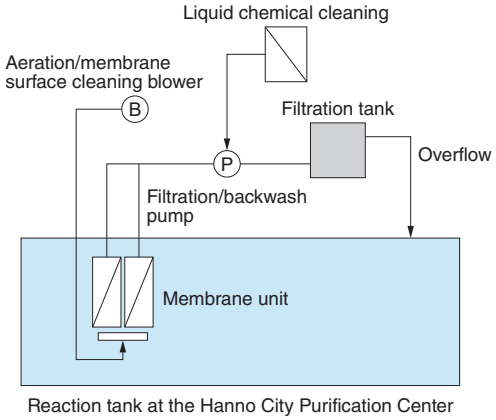
The purpose of this research is the verification of the effect of MBR application on the combined sewer system. In the case of sewer by the combined sewer system, the volume of influent sewage water into a treatment plant during rainfall is increased compared with the one in sunny weather because rainwater is added to the influent water. For solid-liquid separation in the final sedimentation tank, the separation efficiency is lowered when the flowrate is increased by rainfall. As a result, the efficiency of the removal of Suspended Solids (SS) and coliform group is lower. If the MBR filtration flux without containing the SS and coliform group can be increased for the treated water while the influent water volume is increased, it is then possible to make enough solid-liquid separation even during rainfall. In so doing, cases of water discharge simple water treatment process and water discharge without any treatment can be decreased and it is likely possible to reduce the organic load on the effluent water to be discharged to public water areas (rivers, lakes, and sea.)

According to current research results, the submerged type MBR with Ceramic Flat sheet Membranes (CFMs) can be operated without sacri-

Table 1 Outline of the Hanno City Purification Center

The Hanno City Purification Center is a medium-scale sewage water treatment plant where the combined sewer system is partly adopted.

Item	Contents
Services commencement	April, 1966
Sewerage system	Partial combined sewer system
Processing capacity (Daily Max.)	33,800m³/d
Processing water volume on fine day	20,365m³/d (Achievement in Fiscal 2015) 20,089m³/d (Achievement in Fiscal 2016)
Existing series	4 series
Processing system	Standard activated sludge method



Reaction tank at the Hanno City Purification Center

Fig. 1 Flow Diagram of the Testing Facility

In the Hanno City Purification Center, a series of filtration test was carried out in an reaction tank. Our CFM units were directly submerged into an reaction tank.

Table 2 Result of Water Quality Analysis

Compared with the effluent water, the membrane filtration water offered a better quality of treated water.

Item	Membrane filtration water (Average: n=4)	Effluent water (Monthly average)
SS (mg/L)	<1	<1～3 (1)
BOD (mg/L)	<1～1 (<1)	1.1～3.0 (1.8)
No. of coliform groups (pc./100mL)	<10	<10

n: No. of samples
Limit of SS detection: 1mg/L
Limit of detection of coliform groups: 10 pcs./100mL

ficing the functions of biological treatment and membrane filtration even though (1) continuous operation was maintained for 4 hours while the MBR processing flowrate was increased 3 times in rainy weather and (2) continuous operation was maintained for 24 hours while the MBR processing flowrate was increased two times. Based on the above verification result, we submerged our CFMs unit directly into the reaction tank at the Hanno City Purification Center and conducted a continuous operation test by making changes in the filtration flowrate in synch with the influent water. This test was to verify operational conditions, effluent water volume, and the effect of the reduction of loading.

2.2 Method of Verification and Evaluation

A verification test was carried out at the Hanno City Purification Center where the combined sewer system is partly adopted. For this testing, our CFM units were directly submerged into the reaction tank. The Hanno City Purification Center is a sewage water treatment plant of the partial combined sewer system and its present treatment capacity is 33,800m³/d. A standard activated sludge method is adopted there. **Table 1** shows an outline of the Hanno City Purification Center. **Fig. 1** shows a flow diagram of the testing facility and **Table 2** shows the result of water quality analysis. We referenced the results of our past researches and determined the fundamental flux and the membrane surface cleaning aeration volume.

We tried to change the flux level in proportion to the influent water volume into the Hanno City Purification Center with assumption that the fundamental flux (flowrate ratio = 1) was 0.64m³/(m²·d) for this testing facility. When the flowrate ratio was 1 or less, operation was maintained at the fundamental flux due to the lower limits of the filtration pump's performance. In consideration of the operational limits of equipment in the plant, the target value of membrane suction pressure was fixed at 45kPa for safe operation. If this limit was exceeded, inline liquid chemical cleaning (Sodium hypochlorite: Concentration 1000mg/L, Chemical cleaning time 30 minutes) was carried out. No periodic inline liquid chemical cleaning was implemented at the predetermined date and time.

In order to evaluate the treatment function and capability, membrane filtration water and effluent water were sampled to measure the Biological Oxygen Demand (BOD), SS, and the number of coliform groups.

2.3 Test and Consideration

(1) Result of operation in temperate weather

Fig. 2 shows the result of operation in temperate weather. On the testing day, there was no rainfall and it was mild throughout the day. There was,

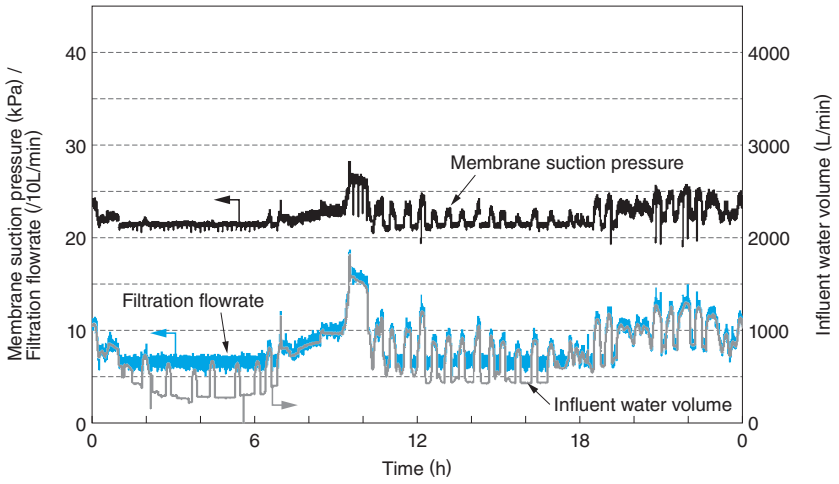


Fig. 2 **Result of Operation in Temperate Weather**

The influent water volume increased twice for about 30 minutes, but the membrane suction pressure did not exceed 45kPa.

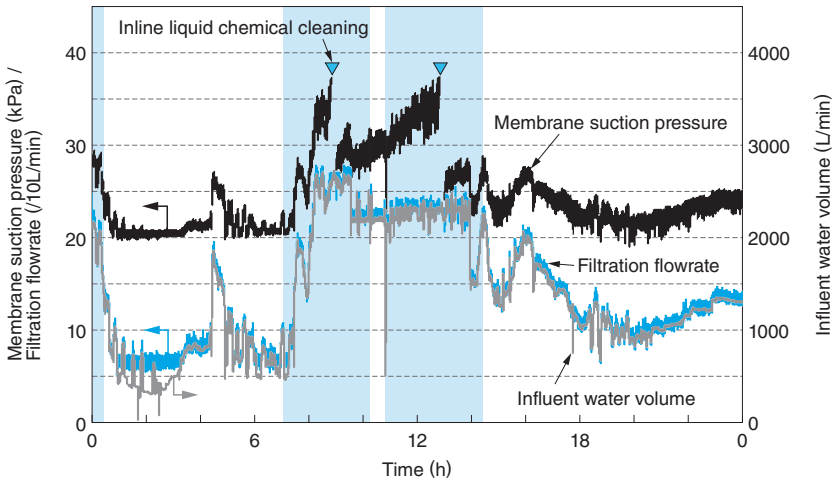


Fig. 3 **Result of Operation during Long and Weak Rainfall**

There was weak and intermittent rainfall for a long time and inline liquid chemical cleaning was carried out twice. After the rainfall ceased, the membrane suction pressure remained stable.

however, a period when the influent water volume was doubled for about 30 minutes from 9:30 to 10:00. Along with this phenomenon, membrane suction pressure was also raised but never exceeded 45kPa. When the flowrate ratio was returned to 1, the membrane suction pressure was also recovered up to the initial pressure.

(2) Result of operation during rainfall

Fig. 3 shows the result of operation during long and weak rainfall and **Fig. 4** shows the result of operation during short and strong rainfall. In both cases, the shaded box in the diagram indicates the time zone when there was rainfall.

(a) Result of operation in long and weak rainfall

Fig. 3 shows the data obtained while there was an intermittent weak rainfall for a long duration of time over two days. On the first day from 14:00 to 20:00 and from 22:00 to 3:00 on the following day, an intermittent but weak rainfall was observed. Approximately 2 hours after the start of rainfall, the filtration flowrate attained the maximum level of about 4 times. At that time, the membrane suction pressure exceeded 45kPa and the first inline liquid chemical cleaning was carried out.

The influent water volume then began to settle down but the filtration flowrate continued to maintain a level of about 3 times. Approximately 5 hours after the filtration flowrate at 3 times began, the second inline liquid chemical cleaning was carried out. After the rainfall, the influent water volume became 1.5～2 times and the membrane suction pressure returned to its stable level.

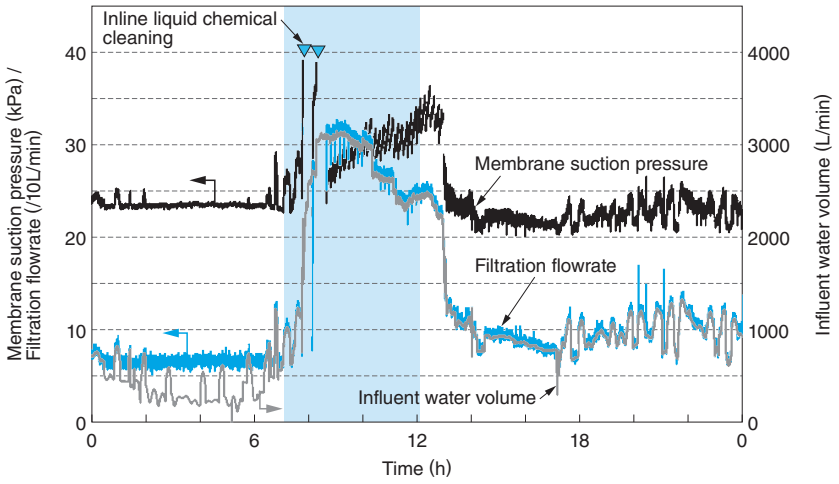


Fig. 4 **Result of Operation during Short and Strong Rainfall**

There was a strong rainfall for a short time and the influent water volume increased to a maximum of 5 times. After the inline liquid chemical cleaning repeated twice shortly after the occurrence of an increase in influent water volume, continued operation could be carried out.

(b) Result of operation in short and strong rainfall

As shown in Fig. 4, rainfall continued from 7:00 to 10:30. As a result, the influent water volume continued to be approximately 5 times for about 3 hours. Immediately after the filtration flowrate had attained 5 times, the membrane suction pressure deviated from 45kPa and, the first inline liquid chemical cleaning was carried out. Even after the first inline liquid chemical cleaning, membrane clogging was not cleared away and the 45kPa level was exceeded. As such, the second inline liquid chemical cleaning was carried out. After this second inline liquid chemical cleaning, operation could be continued without the execution of inline liquid chemical cleaning despite that the filtration flowrate was maintained at the 5 times the level. After the rainfall and settlement of influent water volume around 1.5 times, the membrane suction pressure came down to a stable level without inline liquid chemical cleaning. The aforementioned suggests that stabilized filtration is possible during operation irrespective of rainfall time and amount.

(3) Result of water quality analysis

As shown in Table 2, SS and coliform groups were not detected from the membrane filtration water throughout all analytical activities. Regarding the BOD, the result was favorable and showed a positive figure that was less than 1mg/L on average. Although the effluent water duly satisfied the effluent standard, the membrane filtration water showed a far more favorable result. It is suggested that the introduction of MBR assuredly leads to a substantially efficient improvement of effluent water quality.

3 Postscript

As a result of changing the filtration water volume in synch with the changing influent sewage water volume at the Hanno City Purification Center, it was verified that continued operation is possible even during steady rainfall. The verification result indicates that the quality of membrane filtration water is better than that of the effluent water. It is thus expected that application of MBR to conventional combined sewer systems should be promoted.