Basic Development of Membrane Bioreactor Using a Ceramic Flat-Sheet Membrane

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Abstract

The Membrane Bioreactor (MBR) is based on wastewater treatment technology where biological water treatment by the activated sludge method is combined with membrane filtration. This system is advantageous in making the overall water treatment facility compact and obtaining clear treated water suitable for use as recycled water.

There are, however, some problems such as the occurrence of membrane fouling (clogging), and high running cost.

To solve such issues, we developed a Ceramic Flat-sheet Membrane (CFM). The CFM offers outstanding features in mechanical robustness and physical and chemical durability. It has been used in an MBR plant installed in a wastewater treatment plant in Japan. By operation and control making full use of these features there, it realized stable filtration performance and high treated water quality for a long time.

1 Preface

The Membrane Bioreactor (MBR) is based on wastewater treatment technology where biological water treatment by the activated sludge method is combined with membrane filtration. The major features of the MBR are as follows:

(1) easy system maintenance and management,

(2) satisfactory quality of filtered water suitable for the reuse of treated water, and

(3) it is possible to make overall treatment facilities compact

While MBR has these advantages, there are some problems: the occurrence of membrane fouling, product life cycle, and high running cost.

In order to solve these issues, we developed a Ceramic Flat-sheet Membrane (CFM) system.

The CFM offers outstanding features such as mechanical robustness, and both physical and chemical durability. By system operation and control making full use of these advantages, we realized stable filtration performance and maintained satisfactory quality of treated water for a long time. For the verification of such features, continuous operation was carried out for three years at a verification plant where a CFM system is installed. This pilot plant is situated in a wastewater treatment plant in Japan. This paper introduces the result of the verification test.

2 Outline of CFM and Pilot Plant

2.1 CFM

Table 1 shows the basic characteristics of the CFM used at the time of the verification test. Table 2 shows a comparison between our CFM and conventional membranes. Thanks to these characteristics, the CFM-based MBR can secure higher efficiency and a more stable system of operation compared with conventional MBRs.

Table 1 Basic Characteristics of CFM

Features of the CFM are a high permeability, wide applicable operating temperature, and a wide range of pH.

Item	Specification
Type of membrane	Micro filtration membrane (MF membrane), CFM
Material	α-alumina (porcelain: Arita-yaki pottery, Kutani-yaki pottery, firebricks)
Nominal pore size	0.1μm
Water permeability with ion-exchanged water	40m³/(m²·d) at 25℃, 100kPa
Particle retention	95% or more of 0.1μm standard particle at 100kPa
Using conditions	Pressure: −100〜100kPa Temperature: −20〜80℃ pH: 2〜12

Table 2 **Comparison of our CFM and Conventional Membranes**

Compared with conventional membranes, our CFMs offer outstanding operational life and maintainability. With respect to recycling, our products are eco-friendly.

Membrane shape	CFM		Hollow fiber membrane
Material	Ceramic	Synthetic resin (PVDF, PE)	Synthetic resin (PVDF)
Durability	+++ Chemical durability: applicable to a wide range of pH and water temperature	++ Application restricted for some chemicals; not applicable to high temperatures	++ Application restricted for some chemicals: not applicable to high temperatures
Period of performance maintained	15 years	8 years	7 years
Filtration performance	++	++	++ By the effect of entanglement caused by impurities, membrane performance is reduced.
Running cost	+++ Energy consumption reduced by 50% by decreasing the volume of scrubbing air.	++	++
Maintainability	+++ Prevention of fouling by backwash; freedom from membrane deterioration by chemical cleaning	++ Backwash enabled, but caution is needed to prevent membrane destruction.	+ Low cleaning efficiency due to hollow fiber concentration; complicated cleaning process by manpower
Footprint	++ Stable filtration enabled by high flux	+	+++
Recycling	+++ Crushed and recycled	– Incinerated	– Incinerated

Plant factors and operating conditions	
Capacity	System 1: 30m³/day, System 2: 50m³/day
Filtration/backwash time	14.5min/0.5min
Air volume for membrane cleaning	6~10 times the filtration flow rate
MLSS concentration	8000~12,000mg/L
Aerobic tank	1.0mg/L constant control

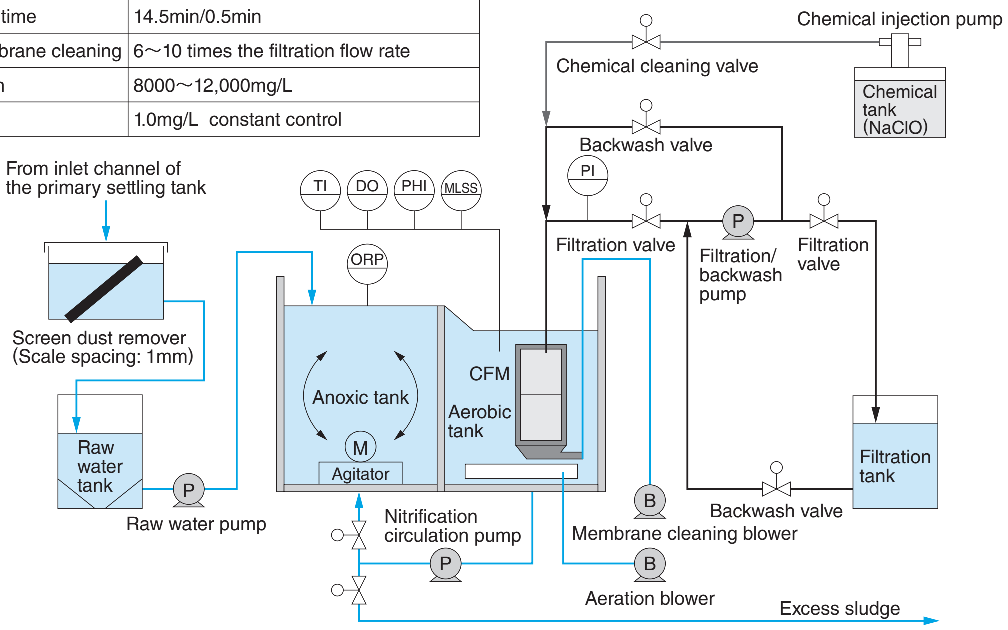

Fig. 1 **Flow Chart of Verification Plant and Design Factors**

Periodic backwash is performed for the CFM to realize stabilized membrane filtration.

2.2 Verification Plant

The pilot plant was installed in the premises of the Hanno City Water Purification Center, Saitama Prefecture, Japan. **Fig. 1** shows the flow chart and design facts of the plant where our verification test was carried out.

The pilot plant is equipped with a bioreactor tank where biological treatment is performed by the activated sludge method. The bioreactor tank is divided into an anoxic tank and an aerobic tank. A CFM unit was installed in the aerobic tank. In this unit, multiple CFM elements were put into modules

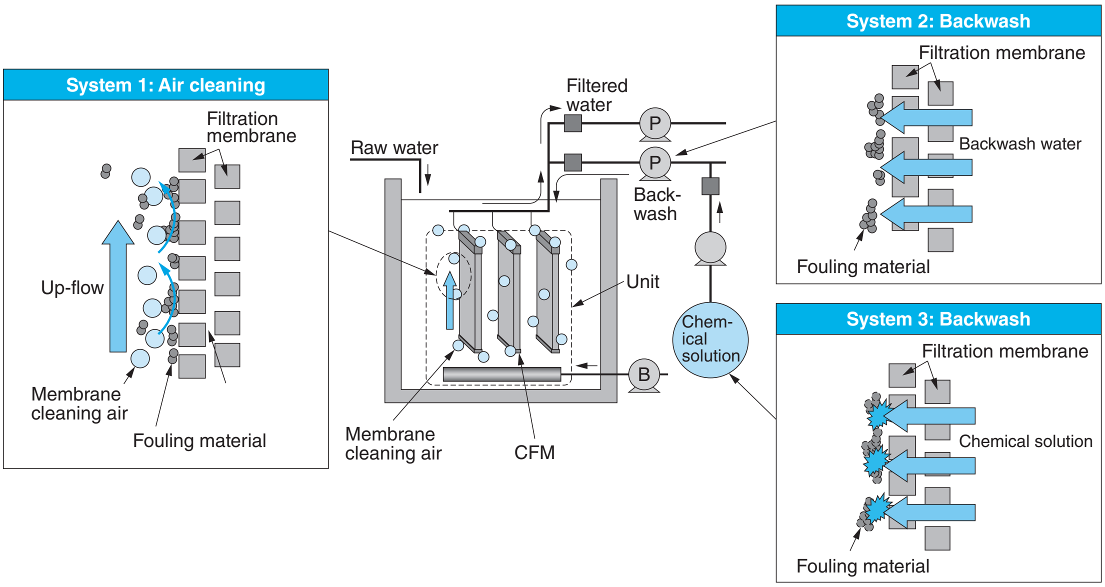

Fig. 2 **Cleaning Method for CFM**

When a backwash technique is used, the CFM greatly reduces the volume of membrane cleaning air. Compared with conventional type membranes, this CFM-based treatment system has more energy saving effect.

that were set in the upper and lower stacks.

The method of daily membrane cleaning is roughly classified into two categories: scouring air cleaning and backwash. Fig. 2 shows each respective membrane cleaning method.

Scouring air prevents the formation of fouling on the membrane surface using coarse bubble force supplied from the bottom of the membrane unit during filtration. This method is generally used for the MBR. There is a problem, however, that the volume of scouring air is large and this raises the running cost.

Backwash is an action to reverse the flowing direction of the filtration water temporarily so that attached substances are removed from the membrane surface. It is a reasonable cleaning method because the physical strength of the ceramic membrane can be effectively utilized. If this backwash is performed periodically, the volume of scouring air can be remarkably reduced. In this manner, we could achieve energy saving for water treatment facilities.

Regarding the impossible-to-remove materials on the membrane surface even by scouring air cleaning or backwash, these are removed by a combination of cleaning with backwash and chemical. During this verification, a solution of sodium hypochlorite in a concentration of 1000mg/L was used once a week.

Using such a plant and cleaning method, a verification test was started in October 2009 and it lasted for about three years.

3 Results and Consideration

During continuous operation of the CFM pilot plant, evaluation of performance characteristics was carried out by making water quality analysis and examination of the Trans-Membrane Pressure (TMP). Table 3 shows the result of water quality analysis on raw water and treated water. Fig. 3 shows variations observed in the TMP and flux during the verification period.

The result of water quality analysis shows the mean, maximum, and minimum values observed from March 2011 to March 2012. During this period, there was no case when the Suspended Solids (SS) value in treated water exceeded 1mg/L. In addition, the mean turbidity of filtered water had been 1 degree and the chromaticity was 10 degrees or below. These values suggest that the outlet water sufficiently met the requirements of water quality standard when used as recycled water.

The TMP and flux data were obtained from the result of measurement during the verification test from October 2010 to March 2012. Flux means the permeability per unit membrane area. At the latter half of the period, stabilized filtration was carried out

Table 3 Result of Water Quality Analysis for Raw Water and Treated Water

Stable and acceptable quality of water was maintained even in the middle of variation of raw water quality.

Item	Raw water			Filtered water			
	Mean value	Max. value	Min. value	Mean value	Max. value	Min. value	Goal value
SS (mg/L)	145	420	48	<1	<1	<1	Mean 1 or below
BOD (mg/L)	198	450	50	2	3	1	10 or below Max. Mean 2 or below
COD (mg/L)	106	450	29	5	7	3	
T-N (mg/L)	23.8	43.0	10.0	6.2	8.7	2.1	Mean 10 or below
T-P (mg/L)	2.1	4.6	0.5	1.4	1.9	0.6	
Turbidity (degrees)	–	–	–	<1	<1	<1	2 or below
Chromaticity (degrees)	–	–	–	8	10	5	10 or below Max.
Escherichia coli (CFU/100mL)	–	–	–	<10	<10	<10	Not more than 10 Max.

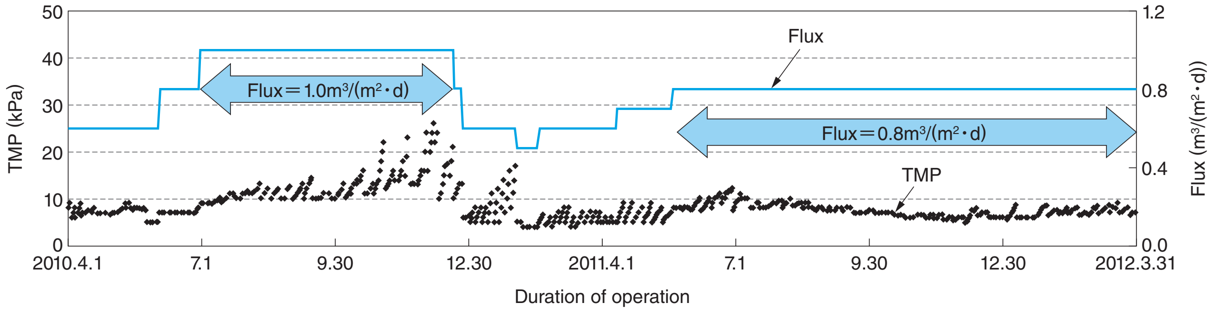

Fig. 3 Variations in TMP and Flux

High flux and stabilized TMP were maintained throughout the period of continuous operation.

at the flux of 0.8m³/(m²·d). This figure indicates a great improvement in performance as compared with a conventional figure of 0.5～0.7m³/(m²·d).

4 Postscript

Using a newly developed CFM unit applicable to wastewater treatment sites, we made a verification test on the unit at a wastewater treatment plant. The obtained results are described below.

(1) Only with a basic cleaning system as shown in **Fig. 1**, we could realize operation at a high flux.

(a) Flux = 0.8m³/(m²·d): For 1 year

(b) Flux = 1.0m³/(m²·d): For 5 months

(2) During continuous operation of the system, quality of filtered water had been maintained under favorable conditions. Such a good result is due to favorable characteristics of the CFM that is free from fracture and deterioration in membrane material.

As reported above, and compared with conventional membrane treatment approaches, we could achieve an outstanding test results from a pilot plant where public sewage water is used as raw water. In the future, we will continue to develop applications of CFMs to wider industrial fields such as treatment of industrial waste and recycled water and also pretreatment of brine desalination, not limited to the processing of municipal wastewater.

Last but not least, we would like to express our sincerest gratitude to the people of the Hanno City Water Purification Center, Saitama Prefecture, Japan, for giving us a chance to implement the verification testing for our research.