Drinking water production by ultrafiltration membrane combined with sand filtration pretreatment

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1-Introduction

The membrane filtration technology has the particularity to be an absolute cut-off filtration that removes all particles bigger than the membrane pore size. The pore size of 0.01μm and the molecular-weight exclusion limit of 100,000 Dalton allow the ultrafiltration membrane to remove all particulate and colloidal matter. Thus the UF filtrate is free of turbidity and microorganisms like bacteria, virus, or Cryptosporidium. The weak point of the membrane technology is the fouling. However, by the control of filtration parameters like the feeding flux or the backwashing cycle, it is possible to avoid a serious clogging of the membrane.

2- Materials and method

From March 1994 to December 1996, an ultrafiltration membrane pilot plant (see Figure 1 and Table 1) was installed in Nagahama water purification plant (Nagahama City) and was run with the Lake Biwa water. The raw water was taken 4 m under the lake surface and 700 m distant from the shore. From February 1995, a medium-rate up-flow sand filter (SF) was installed before the UF membrane as a pretreatment. The membrane characteristics are given in Table 1.

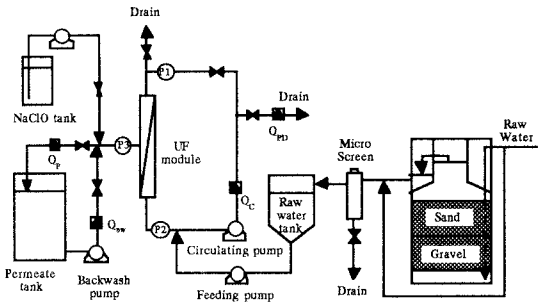

Fig. 1 : Schematic diagram of the UF pilot plant

Table 1: Characteristics of UF membrane module

Material of UF membrane	Cellulose derivatives
Pore size of UF membrane	10 nm
Molecular-weight exclusion limit	100,000 Dalton
Inner / Outer diameter of a hollow fiber	0.93 mm / 1.67 mm
Length of a hollow fiber	1.30 m
Number of hollow fibers by module	2060
Total filtration surface area by module	7.2 m^2
Initial permeability at 20°C	2.6 10^{-3}m.h^{-1}.kPa^{-1}

3- Water quality

The Lake Biwa water was characterized by a stable quality over the year, and was usually suitable to produce drinking water by ultrafiltration process. The average raw water turbidity was 2.3 mg/L as Standard Kaolin, TOC was less than 2 mg/L and Potassium permanganate demand was 3.52 mg/L. Metallic elements such as iron or aluminium were detected in low concentrations, around 0.1 mg/L. However some peak of turbidity and general water quality degradation were observed during typhoon and windy weather (see figure 2).

As expected, the UF filtrate turbidity didn't increase over 0.1 mg/L and was usually non detectable whatever was the raw water turbidity. Further more, microorganisms such as general bacteria, E.Coli, and plankton were never detected in the UF filtrate. The $KMnO_4$ demand and TOC were respectively less than 1.5 mg/L and 2.6 mg/L. (see Table 2). The ultrafiltered water was shown to meet the Japanese health standard of the drinking water and for most of the time reached the goal for comfortable water quality.

Table 2 : Water quality (average)

Parameters	Without pretreatment 1994.3~1995.1		Sand filtration pretreatment 1995.2~1996.12		
	Raw water	UF water	Raw water	SF water	UF water
Temperature (°C)	18.6		15.8		
Turbidity (mg/L SK)	2.26	0	1.92	0.61	0
Color (mg-Pt/L)	6.26	1.24	7.04		1.05
pH	7.41	7.41	7.55		7.24
$KMnO_4$ consumption (mg/L)	3.52	2.58	3.33		2.19
TOC (mg/L)	1.82	1.44	1.72	1.53	1.42
UV_{260} (m^{-1})	2.1	1.8	2.3	1.8	1.4
Total bacteria (Unit/mL)	439	0	328		0
Fe (mg/L)	0.08	0	0.11	0.03	0.01
Mn (mg/L)	0	0	0.01	0	0.03
Al (mg/L)	0.08	0.05	0.12	0.07	0.06
Si (mg/L)	0.08	0.08	1.47	1.48	1.31
Ca (mg/L)	9.52	10.03	12.65	12.80	12.97
Mg (mg/L)	1.97	2.17	2.20	2.24	2.24

4- Direct filtration

The UF membrane was fed with the Lake Biwa water without pretreatment and was then run in a cross flow mode (cross flow velocity at 0.9 m/s) from April 1994 to January 1995. Until July the flux was gradually increased from 0.035 to 0.08 m.h^{-1} and the backwashing cycle was 2700 s. Then the filtration time was fixed

at 3600s and the feeding flux at 20°C varied in a range between 0.08 and 0.11 $m.h^{-1}$ until December (see figure 3). During six month, from June to December 1994, the membrane permeability was quite stable around $1.7\times10^{-3} m.h^{-1}.kPa^{-1}$ (see figure 4) and the transmembrane pressure was in a range between 30 and 80 kPa. However, in the middle of December, the feeding flux had to be decreased to avoid the rapid clogging of the membrane and keep the filtration condition stable.

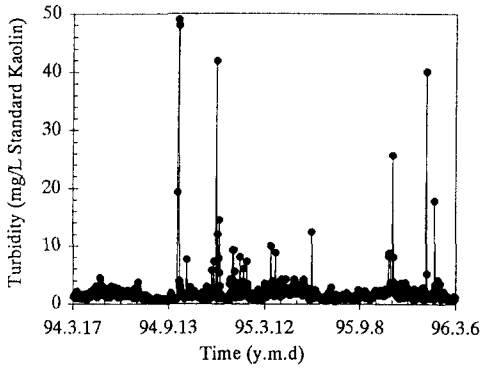

Fig. 2 : Lake Biwa turbidity

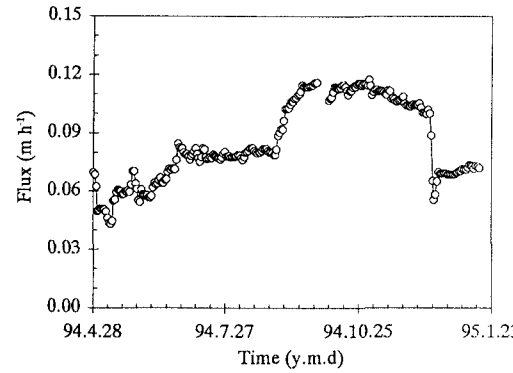

Fig. 3 : Feeding flux at 20°C

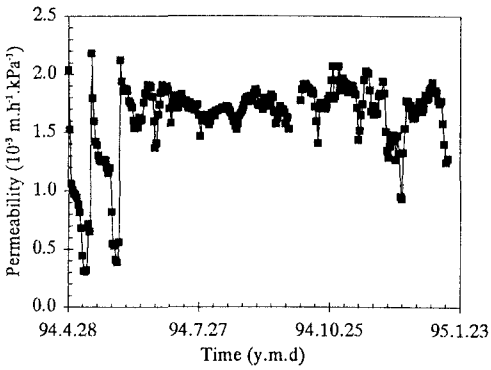

Fig. 4 : Membrane permeability at 20°C

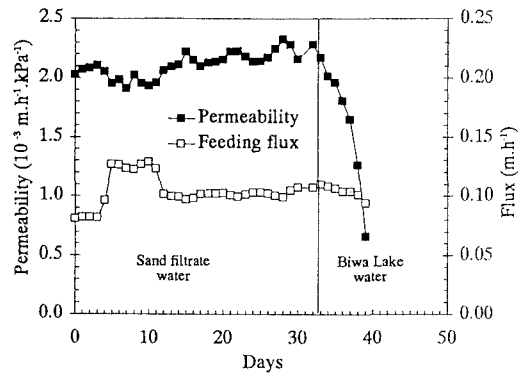

Fig. 5 : Membrane permeability and feeding flux at 20°C (96.03.09 to 96.04.26)

4- Sand filtration pretreatment

In the second part of the study , a basic pretreatment constituted by a medium-rate up-flow sand filter was used before the ultrafiltration membrane. This filter was run with a constant rate of 20 $m.day^{-1}$.

4.1- Effect on water quality

The sand filter main effect was the removal of the particulate matter contained in the Lake Biwa water. Thus the raw water turbidity was reduced by 70% (see table 2). Further more Iron and Aluminium which were found to be the clogging material were respectively removed by 73% and 58%. The water main treatment was realized by the ultrafiltration membrane process, thus the UF filtrate quality was not affected by the sand filtration.

4.2- Filtration performances improvment

The sand filtration pretreatment allows the UF process to support feeding flux (at 20°C) between 2.4 and 3 $m.day^{-1}$. However, the membrane fouled very rapidly when it was fed by the Lake Biwa water in such extreme condition (see figure 5). On the other hand, the UF process could be run in dead filtration mode, which reduced the energy cost by more than 40%. For more than 6 month the membrane permeability (at 20°C) was found stable in the range of 1.8 to 2 $10^{-3} m.h^{-1}.kPa^{-1}$ then the feeding flux (at 20°C) was 0.1 $m.h^{-1}$ and the backwash periodicity was 3600 s.

5- Conclusion

The UF filtrate quality was all the time better than the Japanese drinking water standard. The process could be run in stable conditions for 6 month at 0.08 $m.h^{-1}$ (1.92 $m.day^{-1}$) at 20°C. Improvement of the filtration performances could be expected by using a basic sand filter pretreatment, however the final UF filtrate quality is not modified by such prefiltration.