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방류수 재이용을 위한 합성투과 여재 여과

Synthetic Permeable Medium Filtration for Secondary Effluent Reclamation

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Abstract

In the present study a feasibility of a novel filtration process using synthetic for secondary effluent reclamation was investigated. Polyurethane was chosen as a filter medium among tested three media. Compressibility and up-flow velocity were changed to determine the optimum operation for the system. An equation was introduced to express the relationship between the removal efficiency and up-flow velocity. In pilot study, the synthetic medium filtration with compression showed very stable effluent quality without clogging trouble, though the system operated with 3 times higher filtration rate and much longer backwashing interval than conventional systems.

Key words: Filtration, permeable media, reclamation, secondary effluent, synthetic media
주제어: 여과, 투과성 여재, 하폐수 재이용, 이차 처리수, 합성여재

1. INTRODUCTION

Securing water resources become major issue due to population explosion, uncontrolled use, inefficient management and pollution. The demand of water supply is continuously increasing for irrigated agriculture, industry and urban consumption. There are no other solutions to overcome the limitation of the water resources without recycling. Water reclamation and reuse could be provided very effective measures to protect and save water resources, and these measures must be considered both environment and public health.

In Korea, 184 sewage treatment plants have been discharged 20 million tons of treated effluent annually and only 2.4% out of the effluent was used for water reuse.

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According to the Ministry of Korea, to have the reuse percent of secondary effluent increased by 5%, it could be the same result of having a dam holds 360 million tons of water (MOE, 2002). In contrast to the water reuse in building as supplemental in-building water resources, the secondary effluent reclamation of wastewater treatment could be produced a lot more and used in many purposes. Therefore, the secondary effluent reclamation from wastewater treatment plant has the potential to be a key process to save water resources and protect environments.

Numerous filtration technologies have been conducted and applied to treat domestic and industrial wastewater. Sand and anthracite are most commonly used wastewater filtration media. However, conventional filter put restriction on operation parameters such as porosity, filter depth and flowrate. A synthetic medium filter have been proven to be one of the processes enables successfully reject in the wide range of suspended solids (SS) and turbidity from secondary effluent (Caliskaner et al., 1999; Jimenez et al., 2000).

The main objective of this study is to investigate a performance of synthetic medium filtration in secondary effluent applications. Factors which affect on the performance of filtration process include compressibility, flowrate and filter materials were investigated to evaluate the synthetic medium filtration.

2. MATERIAL AND METHODS

A pilot scale filtration facility was installed at Gwangju municipal wastewater treatment plant in Gyeonggi province, Korea. The plant has a capacity of 20,000 m^3/day and discharges the wastewater effluents to the Gyeonan River, a small branch river of Han River in Seoul. A pump was installed in the overflow well after the secondary clarifier.

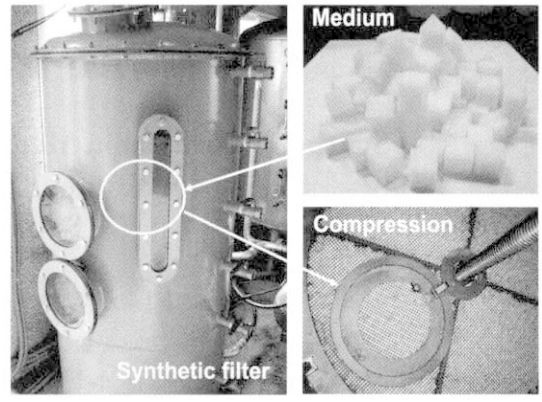

Fig. 1. Pilot scale synthetic medium filter.

The wastewater plant has been operating with an activated sludge process as a secondary treatment since 1990. The source water characteristics are present in **Table 1**, along with the standards for reuse for toilet flushing and non-potable reuse. Note that the water qualities were quite fluctuated during the experiments due to the variation of influent in the real wastewater plant. Among the standards, a reclamation process is necessary to reduce turbidity as an essential contaminant.

The experiments were conducted with control sand filter, lab-scale synthetic filter, and pilot scale facility described as **Table 2**. Sand filter was established in the pilot plant in parallel. Laboratory synthetic medium filter

Table 1. Source water characterizations and standards for reuse for toilet flushing and non-potable reuse

Parameters	Units	Raw Water	Wastewater Effluent	Standards for Reuse
Turbidity	NTU	38-105	2.6-5.3	< 2
Color	Pt-Co unit	41	20-33	< 20
COD_{Mn}	mg/L	51.9	11.2-15.5	< 20
DOC	mg/L	10.9	6.7-7.6	NA*
Total Coliform	$100mL^{-1}$	3.0×10^5-8.0×10^6	$2x10^4$-$7.3x10^4$	ND**
pH	-	6.8-7.5	7.1-7.3	5.8-8.5

*NA: not available, **ND: not detected

Note: Other standards which are not listed in Table 1 include chlorine residual (combined), appearance, BOD, and odor.

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Table 2. Characteristics of filter systems used in the experiments.

Parameters	Control Sand Filter	Lab-Scale Synthetic Filter	Pilot Scale Synthetic Filter
Dimension(mm)	100(D) × 500(H)	250(D) × 2,200(H)	1,200(D) × 1,800(H)
Filter bed depth	20	Gravel/Sand:20/40	700
Compression rates(%)	0-80	0	0-30
Back-washing type	Water	Water and air	Water and Air
Flow rate(m^3/m^2/day)	18-92	150	72-350
Flow type	Up-flow	Down-flow	Up-flow

was operated to select medium material and to investigate major affecting factors on synthetic medium filtration. The secondary effluent that used in laboratory study was same as the pilot plant. The pilot scale synthetic medium filter is shown schematically in **Fig. 1**.

The SS, turbidity and other water quality parameters measured according to the procedures by *Standard Methods* (APHA, 1998). Laser diffraction spectrometer (Coulter, LS100Q) was used to analyze the particle size distribution of secondary effluent and reclaimed water.

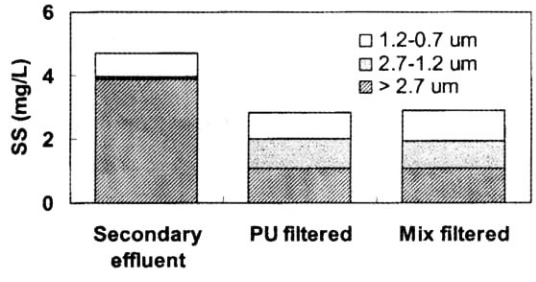

Fig. 2. Variation of SS at intervals of particle diameters.

3. RESULTS AND DISCUSSION

3.1. Effects of media materials

Three types of synthetic resins were applied to investigate an appropriate filter medium in filtration system. The performance of three media was summarized in **Table 1**. Polyurethane medium showed the best removal efficiency among applied media, though activated carbon coated polyurethane medium was expected a good performance. It means that coated carbon did not play a significant role in filtration. Organic matter did not removed by synthetic medium filtration. Carbon coated medium did not show even soluble organics. Polyvinyl alcohol medium containing less porosity showed slightly better color removal, but turbidity removal efficiency was poorer than polyurethane medium. **Fig. 2** shows variation of SS concentration according to particle size interval. Over 2.7μm of particle diameter occupied eighty percent of total SS in secondary effluent. However, this fraction reduced to about thirty percent after synthetic medium filtration. It indicated that the larger particles could be removed more preferentially.

3.2. Effect of up-flow velocity on removal efficiency

One of most affecting factors on filter efficiency is

Table 3. Secondary effluent and filtered water quality

Parameters	Secondary Effluent	Polyurethane (PU)	Carbon Coated Polyurethane (Mix)	Polyvinyl alcohol (PVA)
Turbidity (NTU)	2.52	1.56(38%)*	1.69(33%)*	2.00(21%)*
Color (Co-Pt unit)	17.3	16.0(7.2%)*	16.3(5.8%)*	15.0(13.0%)*
CODCr (mg/L)	24.5	22.5	21.8	23.0
CODMn (mg/L)	8.1	7.3	7.5	7.1
BOD (mg./L)	9.5	8.9	8.8	8.7
pH	7.38	7.47	7.48	7.51

*Removal Efficiency

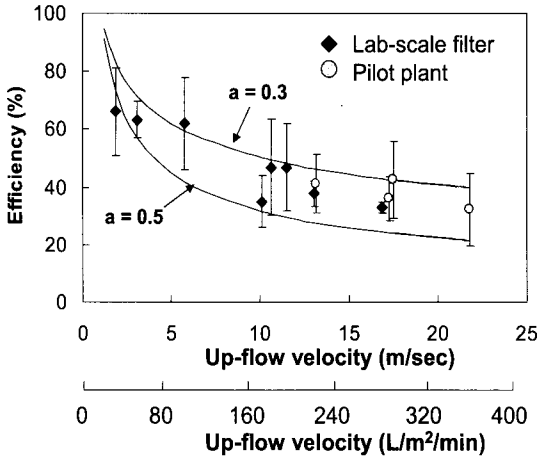

Fig. 3. Relationship between up-flow velocity and turbidity removal efficiency.

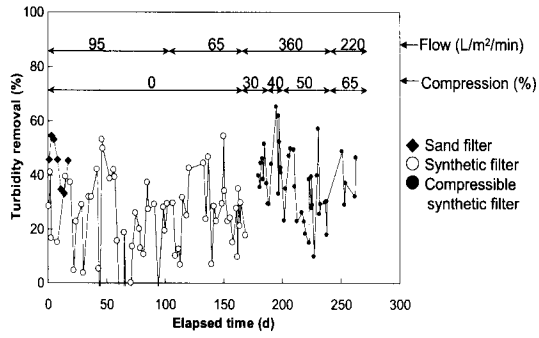

Fig. 4. Pilot plant performance of turbidity removal.

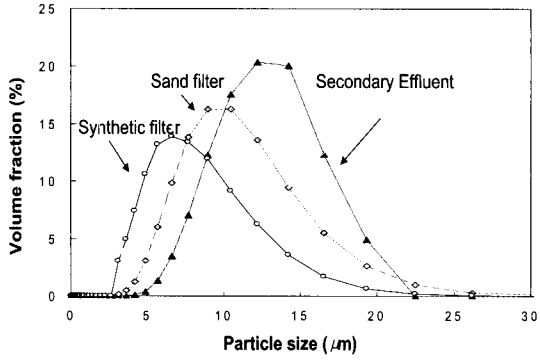

Fig. 5. Particles size distribution of secondary effluent and filtered water.

filtration rate. Fujita (1977) have suggested the relationship between filtration rate and turbidity removal efficiency in sand filter. His relationship explained regarding the contact efficiency due to gravity in down-flow system. Similar to Fujita's equation, an exponential equation could be expressed to investigate the relationship up-flow velocity and turbidity removal as follows:

$$\eta = k\,(1/v^{a})$$

Where, η = turbidity removal efficiency

v = up-flow velocity

a, k = coefficients

Fig. 4 shows experimental results of turbidity removal and up-flow velocity under several conditions. Exponential coefficient "a" could be calculated 0.3 to 0.5 as shown in the same figure. These values were less than those of the sand filter. Fujita (1977) calculated the coefficient in the range from 0.5 to 0.67. It may indicate that synthetic medium filter less affected by filtration rate or up-flow velocity so synthetic medium filter could operate higher filtration rate than conventional filter.

3.3. Pilot scale filter operation

Performance of synthetic media system in this research was mainly affected by parameters such as inflow water quality, filter media, filtration rate and compressibility. The pilot plant was established in order to remove SS and turbidity before UV disinfection process in water reclamation system. In the initial stage of experiment, sand filter operated for 20 day in parallel with synthetic medium filter. However, sand filter caused significant troubles in secondary effluent treatment. Major problems were frequent occurrences of filter layer clogging, since maintenance of the wastewater treatment plant was not well organized. The plant cleaned manually the secondary sedimentation facility once or twice a week. Although average water quality of secondary effluent was good enough, turbidity increased up to 50 NTU during cleaning of sedimentation for several hours. Synthetic medium filter, however, reduced clogging problems, even though effluent quality was increased instantly to 20 NTU. Synthetic medium filter represented short circuit

like phenomenon. As shown in **Fig. 4**, turbidity removal efficiency declined to almost 0% in the normal range of inflow turbidity from 2.0 to 3.0 NTU. Therefore, the filter medium was compressed to 30% after 70 days operation. Compressed medium filter showed very stable turbidity removal characteristics with high efficiency.

Particle size distribution of secondary effluent, sand filter effluent and synthetic medium filter effluent was shown in **Fig. 5**. In secondary effluent, median particle size was calculated 15μm. After filtration, it reduced to 10 μm in the sand filter and 7μm in the synthetic medium filter.

4. CONCLUSIONS

The secondary effluent from wastewater treatment plant was treated with synthetic medium filter. To evaluate the feasibility of water reuse, the various factors which could be affecting the system performance were changed. The main conclusions of this study are:

1. Three types of filter media were tested to select optimal medium for filtration yet the performance did not show significant difference among three media.

2. Compressibility and up-flow velocity affected the removal efficiency of turbidity. The relationship between removal efficiency and up-flow velocity could be expressed using a suggested equation.

3. In pilot operation, synthetic medium filtration showed two major advantages of filtration rate with long washing interval and no clogging over conventional sand filtration.

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