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Toward an Optimization of the Backwashing Process in the Flexible Fiber Filter

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Abstract: Backwashing process was used to recover the retention capacity of a deep bed filter. A field scale fiber filter was operated with an in-line injection of a coagulant for the treatment of natural surface water (Nak-dong River in Korea). A mass balance of SS could be made thus allowing a direct estimation of the effectiveness of the backwashing process. The purpose of this paper was to study the influence of two parameters of backwashing (air injection and number of backwashing stages) on its effectiveness. The backwashing efficiency was estimated through the initial pressure drop after the backwash, the effluent quality, the duration of the filtration time between two successive backwashes, and the detached mass of retained suspended solids. Conditions could be found for removing 99% of the retained SS. As a general conclusion, the effectiveness of backwashing mainly depended upon air injection. The duration of air injection and the number of sequences were the most important factors related to the efficiency of backwashing.

Keywords: Backwashing, deep bed fiber filtration, air injection, backwashing stages

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INTRODUCTION

During the last years, an innovative deep bed fiber filter has been developed. The filtration velocity of this filter could be 20 times higher than that in a conventional rapid sand filter. Several wastewater treatment plants in Korea are now equipped with a fiber filter as a tertiary treatment (1). More recent research on fiber filter proved that this fiber filter could be used for drinking water production and could be an alternative to the coagulation, flocculation and sedimentation steps (2, 3, 4).

General filtration processes are divided into filtration and backwashing processes. The backwashing process is used to recover the retention capacity of the filter. Deep bed filtration implies a sequence of filtration followed by a backwash step (5, 6). A field scale filter was operated with an in-line injection of a coagulant for the treatment of natural surface water (Nak-dong River in Korea) for the purposes of this study being the optimization of the backwash step. A mass balance of SS could be made thus allowing a direct estimation of the effectiveness of the backwashing process.

MATERIALS AND METHODS

Materials

Nak-dong River water was used as influent water without pre-treatment. The turbidity of the water ranged from 6.5 to 11.5 NTU and the Chlorophyll-a concentration (characteristics of Algae) was between 11.5 and 41.2 μg/L during the study period. The pH was not controlled as it varied in a proper range for coagulation with an average value of 8.05. Water qualities of Nak-dong River were shown in Table 1.

Full-Scale Fiber Filter

A field-scale fiber filter with an inside diameter of 650 mm and a height of 1500 mm was installed in a water treatment plant (Fig. 1).

Table 1. Water qualities of Nak-dong river

	Water qualities	
Items	Average	Range
Turbidity (NTU)	9	6.5∼11.5
pH	8.05	7.6∼8.5
TOC (mg/L)	2.84	2.06∼3.611
UV254	0.044	0.036∼0.052
Chlorophyll-a (μg/L)	26.34	11.49∼41.18

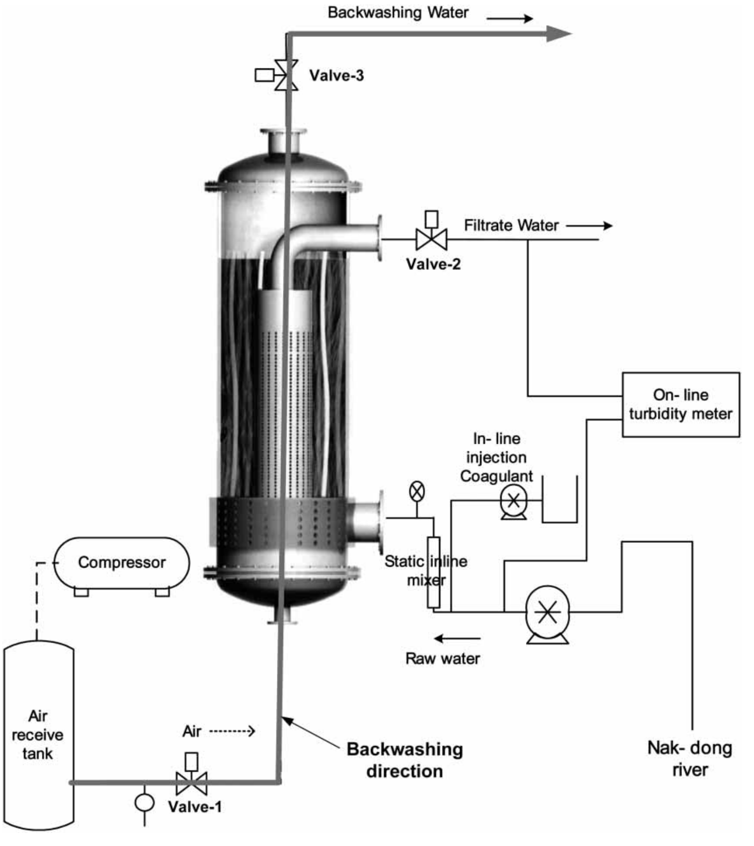

Figure 1. Schematic diagram of backwashing process in full-scale fiber filter.

Polyamide (nylon) fibers of 30 microns were used as filter media. The packing density of fiber was 80 kg/m^3 and the porosity was 93%. The filtration direction was partly radial from the periphery of the filter in its lower part to the axial perforated tube collecting the treated water. During backwash air and water were injected at the bottom of the filter and collected at the top. Coagulants were directly injected by a peristaltic pump to the feed pipe through a static mixer. Coagulation began inside the inlet pipe and the two phenomena of floc growth and retention occurred inside the filter.

Operating Conditions

Backwashing process is used to recover the retention capacity of the filter. Filter backwashing, based on the collapse-pulsing phenomenon studied by Amirtharajah, A. was performed using water and air intermittent injection (7, 8). In this study, water and air backwashing were operated sequentially.

Table 2. Change of air injection

Air + Water	Numbers of backwashing stages	Total backwashing period
7 sec + 30 sec	7 times	294 sec
14 sec + 30 sec	7 times	343 sec

This experiment was conducted at a filtration velocity of 60 m/hr. Backwashing was performed when the turbidity of the treated water reached 1 NTU. Tables 2 and 3 summarized the operating conditions during this study.

RESULTS AND DISCUSSIONS

Effect of Change in Duration Time of Air Injection

In order to determine the optimal backwashing condition, experiments were first performed with different air injection time. It was estimated that the backwashing efficiency was based on the initial pressure drop, the effluent quality, the filtration duration time, the ripening period, and the detached mass of retained suspended solids.

First backwashing was performed under the condition of air injection for 7 seconds and water injection for 30 seconds. The backwashing stages was 7 times.

Figure 2 showed the variations of turbidity and input pressure in the backwashing condition of air 7 sec and water 30 sec. Even though it showed a good recovery of the initial pressure drop and effluent quality, the duration was shortened and the detached mass was only 75% of retained suspended solids.

The mass of SS contained in the backwashed water has been measured and the results are reported in Table 4. The backwashing efficiency with air injection for 7 seconds was not good. Second backwashing was done under the condition of air injection 14 seconds, 30 seconds' water injection time and 7 times of backwashing stages.

Figure 3 showed the variations of turbidity and input pressure with the backwashing condition of air 14 sec, water 30 sec. It also showed a good recovery of the initial pressure drop and effluent quality, but the duration was shortened and the detached mass fraction was 86% of the retained suspended solids. The mass of SS contained in the backwashed water had been measured and the results were reported in Table 4.

Table 3. Change of numbers of backwashing stages

Air + Water	Numbers of backwashing stages	Total backwashing period
14 sec + 30 sec	7 times	343 sec
7 sec + 15 sec	14 times	343 sec

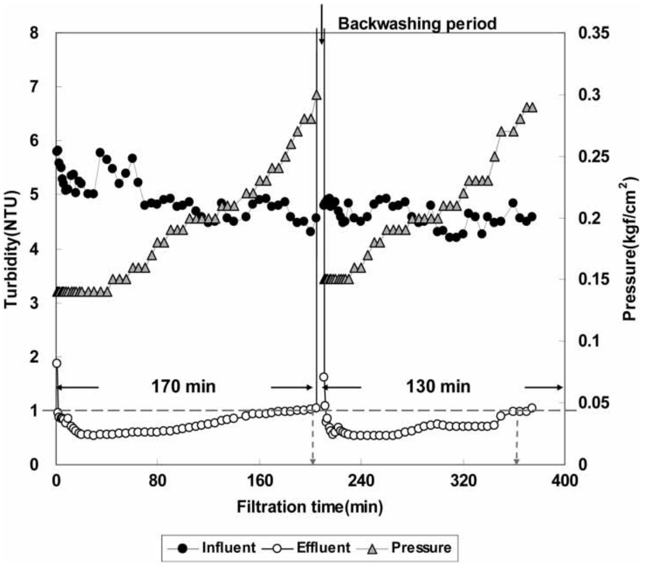

Figure 2. Variations of turbidity and input pressure with backwashing condition of air 7 sec, water 30 sec.

The backwashing efficiency was still not good. But it was shown to be higher than the efficiency of the backwashing condition of air 14 sec, water 30 sec. Thus, air was a important factor to affect backwashing efficiency on fiber filtration.

Effect of Change in Numbers of Backwashing Stages

Figure 4 showed the variations of turbidity and the input pressure under the backwashing condition of air 14 sec, water 30 sec, 7 times of backwashing

Table 4. Calculations of mass of SS in backwashing condition of change of air injection

Mass	7 sec + 30 sec	14 sec + 30 sec
Mass of SS in influent	498 g	630 g
Mass of SS in effluent	72 g	106 g
Mass of SS in filter	426 g	525 g
Mass of SS in backwash water	319 g	450 g
Remaining mass of SS in filter after backwash	107 g (25% of mass of SS inside filter)	75 g (14% of mass of SS inside filter)

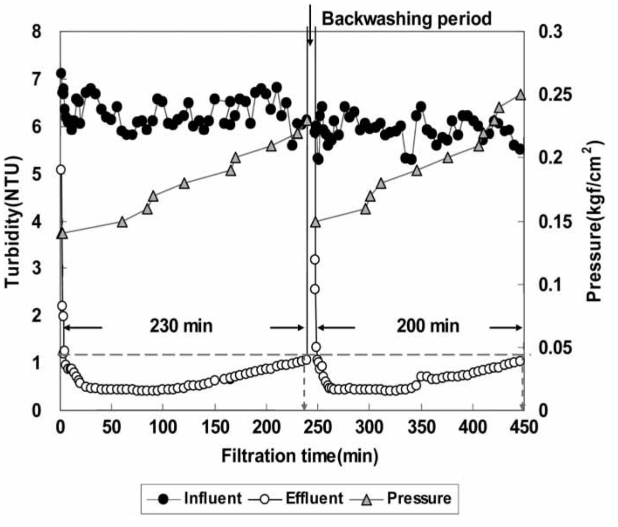

Figure 3. Variations of turbidity and input pressure with backwashing condition of air 14 sec, water 30 sec.

stages. It also showed a good recovery of the initial pressure drop and effluent quality, but the duration was shortened and the detached mass fraction was 86% of retained suspended solids.

Figure 5 showed the variations of turbidity and the input pressure under backwashing condition of air 14 sec, water 30 sec, 14 times of backwashing

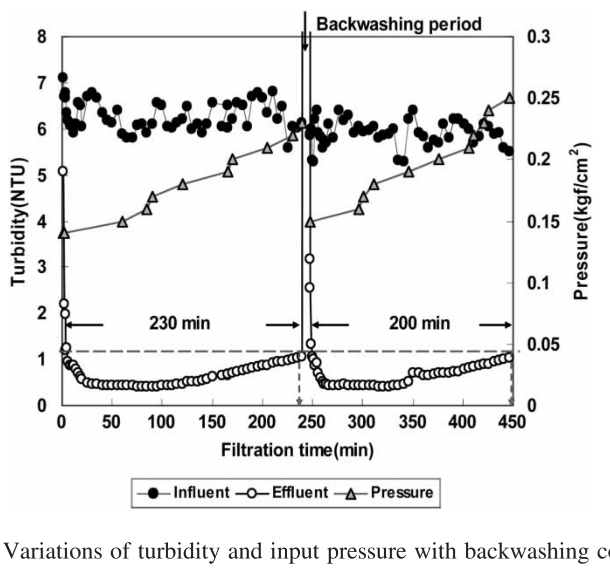

Figure 4. Variations of turbidity and input pressure with backwashing condition of air 14 sec, water 30 sec, numbers of backwashing stages 7 times.

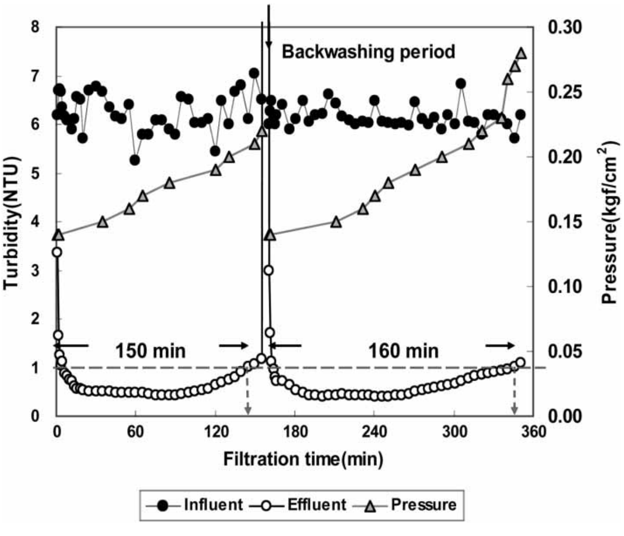

Figure 5. Variations of turbidity and input pressure with backwashing condition of air 7 sec, water 15 sec, numbers of backwashing stages 14 times.

stages. It also showed a good recovery of the initial pressure drop and effluent quality and the duration time of filtration was similar to the duration time of filtration before backwashing. And the detached mass fraction was 99% of retained suspended solids. The backwashing under this condition was very efficient. Table 5 showed calculations of mass of SS under the backwashing condition with change of numbers of the backwashing stage.

As mentioned above, air was an important factor affecting the backwashing efficiency at fiber filtration. Though the same air injection, the numbers of the backwashing stage was an important factor to affect the backwashing efficiency at filtration.

Even though optimal backwashing conditions were determined, it could be said follows.

Table 5. Calculations of mass of SS in backwashing condition of change of numbers of backwashing stages

Mass	7 times	14 times
Mass of SS in influent	630 g	445 g
Mass of SS in effluent	106 g	63 g
Mass of SS in filter	525 g	382 g
Mass of SS in backwash water	450 g	378 g
Remaining mass of SS in filter after backwash	75 g (14% of mass of SS inside filter)	4 g (1% of mass of SS inside filter)

The conditions of backwashing had to be adapted to the particular nature of the clogging. The results presented here were valid only for in-line coagulation of surface water and these results were useful for showing the importance of the air backwashing.

Effect of Continuous Operation

To estimate the stability of filter operation, a continuous operation was performed during 10 hours. Figure 6 showed the variations of turbidity and the inlet pressure during this continuous operation. It can be observed that backwashing was efficient enough to get the same initial value of pressure and a similar duration time of filtration.

The mass of SS contained in the backwashed water had been measured and the results were reported in Table 6. This table showed the summarized results of experiments to determine the optimal backwashing conditions.

Through this table, first of all, it could be said that air was an important factor to affect the backwashing efficiency. Second, the backwashing efficiency was affected by numbers of backwashing stages at same air injection time. Finally, it could be concluded that the backwashing condition with air injection for 7 seconds and water injection for 15 seconds, 14 repetitions of backwashing was the optimal condition.

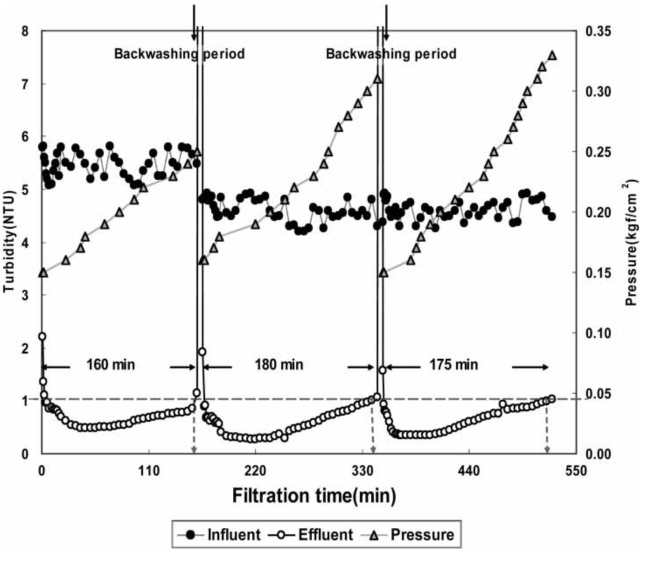

Figure 6. Variations of turbidity and input pressure for the continuous operations.

Table 6. Calculation of the detached suspended solids after backwashing at each set for the continuous operation

Mass	Set 1 (First filtration)	Set 2 (Second filtration after first backwashing)	Set 3 (Third filtration after second backwashing)
Filtration duration time (below 1 NTU)	160 min	180 min	175 min
Mass of the SS in influent	412 g	444 g	440 g
Mass of the SS in effluent	47 g	56 g	60 g
Mass of the retained SS in filter (+ Previous retention mass in filter after backwash)	365 g	388 g + 1 g = 389 g	380 g + 3 g = 383 g
Mass of the SS in backwashed water	364 g	386 g	381 g
Remaining mass of SS in filter after backwash	1 g (0.3% of mass of SS in filter)	3 g (0.7% of mass of SS in filter)	2 g (0.5% of mass of SS in filter)

The volume of backwashed water was only 3% of the volume filtered water during the filtration period. This was an additional proof of the effectiveness of the backwashing operation.

CONCLUSION

Through the experiment to determine the optimal backwashing condition, it could be concluded that both the number of sequences and the air had an effect on the efficiency of the backwash. The optimal backwashing condition was under air injection for 7 seconds, water injection for 15 seconds, and 14 times backwashing stages. It proved that air and the numbers of backwashing stages were important factors affecting the backwashing efficiency at fiber filter. And the volume of the backwashed water produced was only 3% of the volume filtered water produced during the filtration period.

However, the conditions of backwashing had to be adapted to the particular nature of the clogging. The results presented here were valid only for in-line coagulation of surface water and these results were useful for showing the importance of the air backwashing.

Despite more frequent backwashing than a conventional rapid sand filter, the productivity was high and the production of backwash water was small (about 3%).

These conclusions were valid for treatment of surface water of which turbidity was less than 10 NTU. The behavior of the filter during peaks of turbidity or periods with higher turbidity will be tested in the future.

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