OPTIMIZATION PARTICLE SEPARATION FOR BETTER WATER QUALITY IN TREATMENT

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ABSTRACT

The goal of the flocculation, sedimentation, dissolved-air-flotation (DAF) processes are to change the particle size distribution to best suit the subsequent processes. Although several methods exist to evaluate each process, no single universally accepted method has yet to be developed. The purpose of this paper is to present experiences whereby particle counting was used in the diagnosis and optimization of each process. The evaluation is based on particle dynamics, i.e., the change of the number of small and large particles. Some design deficiencies and inappropriate operational conditions in each process have been identified from this method. The effects of changed design in each process have been evaluated by comparing the particle counts at the existing design with particle counts after modification. Because the diagnosis of design may be site-specific, the method presented in this paper will be beneficial in the evaluation of the treatment processes at other water treatment plants leading to low cost, low energy operation.

Key Words: Particle counter, Flocculation, Sedimentation, Dissolved-air-flotation, Diagnosis design, Optimum operating condition

INTRODUCTION

Recently the low-cost and low-energy technology is demanded as a continual policy in the water treatment plants. These situations have been promoted because the direction of high-cost and high-efficiency water treatment plant of advanced countries is difficult to use in the underdeveloped country because of the cost problem.

In the flocculation process of the water treatment plants, there are a water flocculation process that does not use the rapid mixture, while uses the hydrographical fall, a jet-mixing and so on. These are the low-cost and low-energy separation skills. Moreover, recently, an electric condensation plant was introduced to enhance the efficiency and to reduce the quantity of condensation materials (Song et al. [1]). In the rising to the surface plant, the electrolysis method not only has same efficiency with the DAF plant, but also consumes lower power cost has been studied (Han and Shin [2]). In the filtration plant, the process which uses the membrane of an organism has been introduced. However, these new technology are usable only when the new plants were introduced, and they demand high cost of construction work to apply for the existing plant. Therefore, to apply the low-cost and low-energy plan for the existing plants, the correct facilities diagnosis of the existing plants and the best-suited operational conditions should be decided. If the facilities diagnosis can be accomplished precisely, the efficiency can be enhanced with a little assistance about the problematic facilities and apply for the plant that will be designated. Moreover, if the best-suited operation al conditions be found about the excessive operation or wrong operation condition, the water treatment plant can be improved by using the low-energy. These decisions of the facilities diagnosis of the existing plants and the best-suited operation condition can be conducted by measurement of remained turbid waves or tracer test, etc. However, these methods have some demerits that have low sensitivity and are troubles to measure, so better diagnosis process is required.

Therefore, the purpose of this research is to decide the correct diagnosis about the flocculation, sedimentation, and DAF processes to decide the best-suited operational conditions by using the particle counter. If the best-fitted operational conditions be decided, it will be helpful to produce more economical and stable potable water without an introduction of new machines or units in the existing facilities.

EXPERIMENT EQUIPMENT

To decide the correct facilities diagnosis about the existing plant and the best-fitted operational conditions, Laser Trac PC2400D (Chemtrac cop, USA) particle counter is used in this research. The outline feature of the measuring apparatus is showed in Fig. 1. A particle which is flowed in the measuring point expose the distribution of seven channels which are designated the range of size from the sensor department. The sensor department is constituted of an infrared razor diode that radiates the light. The light sensor changes the light energy that is radiated from the razor to the electric pressure. Inflow particles are exposed to electric wave value by sensor department razor.

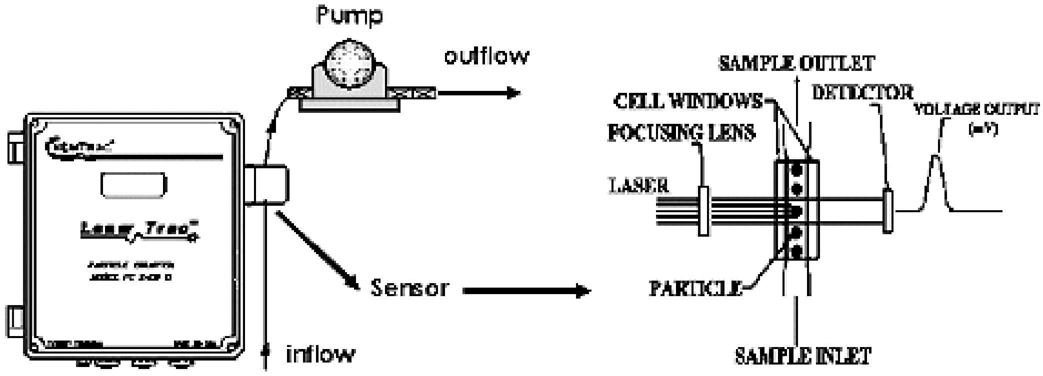


Fig. 1 The structure of particle counter and measuring principle

The measured results are the average value that is measured over 5 times from the measuring point in each condition for particle measuring range of 1 ~100 µm. In each size and range, the particle number was expressed per 100ml. The horizontal axis represented the measuring point and the vertical axis represented the particle number in the measured graph.

OPTIMIZATION EXPERIENCES IN FLOCCULATION PROCESS

To decide the correct facilities diagnosis and the optimum operational conditions, the goal of the relevant plant should be known. The purpose of the flocculation process is making the bigger flocs by collecting the small particles to make big precipitated flocs in the followed sedimentation tank. Therefore, as passing through the each step of the flocculation process, number of small particles should be reduced and number of big particles should be increased. Based on these goals in the flocculation, the diagnosis of the flocculation process and the optimization operation condition can be decided.

The Effect of Opening Arrangement and its Size

The schematic of the first water treatment plant (S-WTP) and experimental points is shown in Fig. 2. Water is influent from point #1 to a rapid mixing tank after adding of coagulants and then flow to flocculation compartments through a distribution channel (#2). The flocculation basin forms flocs as a gradual decreased mixture, such as 1st part (#3), 2nd part (#4), 3rd part (#5). Then it flows out (#6) to the sedimentation basin.

The importance of the opening arrangement and size that flow in and out from a flocculation part to the next part have not been recognized. In the S-WTP that is understudy, when water flowed out from the 2nd part to the 3rd part of the flocculation basin as shown in Fig. 3, the opening part was arranged in the upper plant. At the time, when the depth of water is lower than the opening part, the passing area becomes narrow. Therefore, there was flocs break because the velocity of flow becomes faster (Han et al. [3]). Therefore, velocity of flow was reduced by enlarging the size of opening part from 0.8 m* 0.8 m, to 1.2m* 1.2m.

After enlarging the opening size to 1.2 m 1.2 m, the number of small particle in the 3rd part was lower than before in the particle size range of 1~5 µm. That is, when the velocity of flow was reduced as making the opening size large, flocs were less broken. These results have been also reported in the big particle case. Moreover, in the 5~10 µm particle size, there was no increase by broking the flocs, but it has high efficiency because it reports small number of small particle in the opening size after the change.

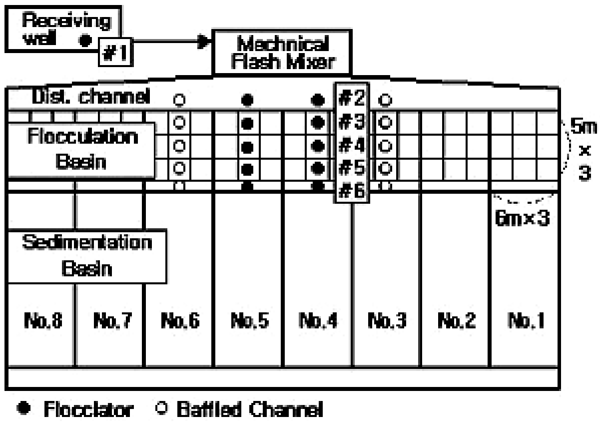


Fig. 2 The schematic of the water treatment plant and experimental points

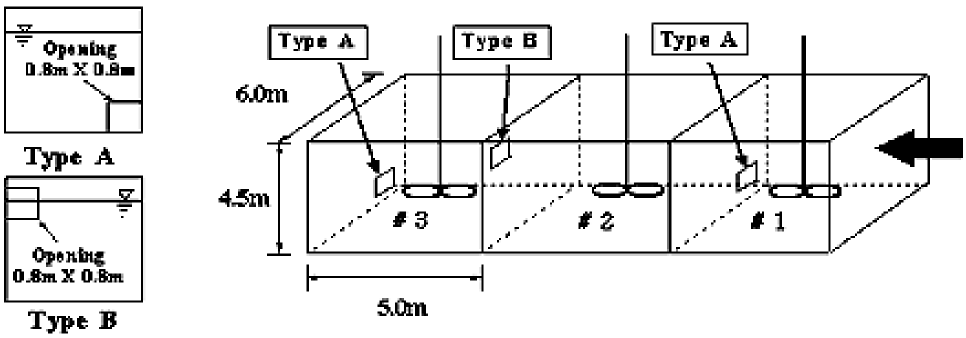
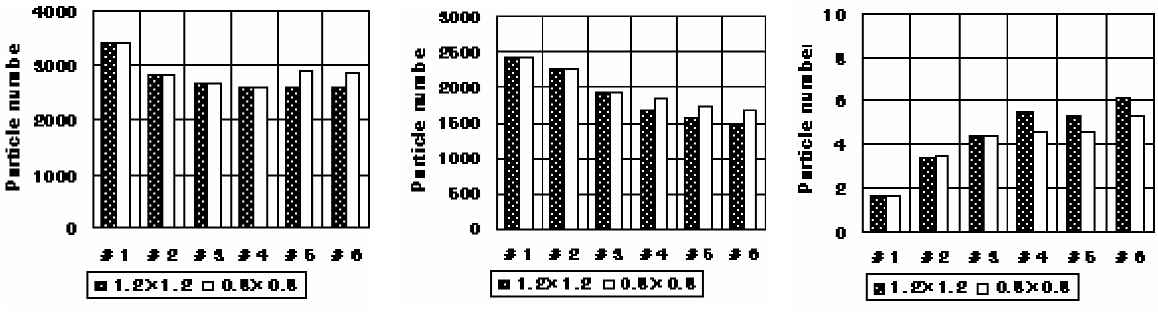


Fig. 3 Flocculation basin details of S- WTP



(a) 1~5 μm (b) 5~10 μm (c) 50~100 μm

Fig. 4 Variation of number of small and large particles at each flocculation stage

The Type of the Flocculator

In this study, to know the form of flocculator which is proper to the purpose of flocculation process, the Pitched blade type (PBT) and the Hydrofoil type were compared. Fig. 5 shows each flocculator form, and Fig. 6 shows the distribution of the average the number of particle in each measuring point.

Analyzing the flocculation efficiency in each flocculator in Fig. 6, all of them are proper to the purpose of flocculation process, the number of small particle were decreased and the number of big particle were increased. However, when we compared the two forms of flocculator, the number of small particle were less and the number of big particles were more in the Hydrofoil type flocculator than in the PBT type. Therefore, the Hydrofoil type flocculator has high efficiency in the flocculation process.

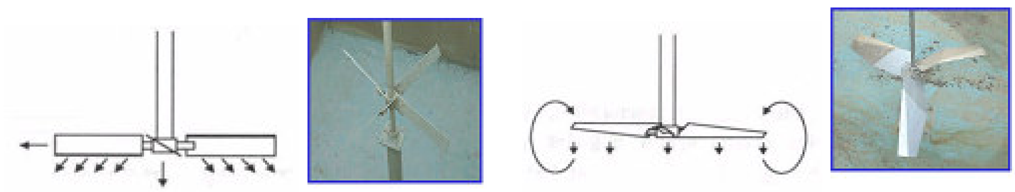
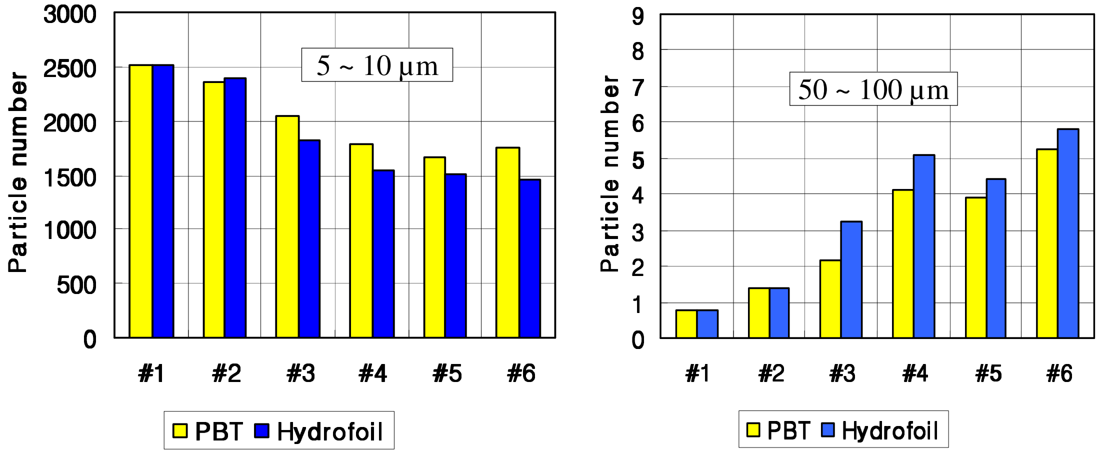


Fig. 5 Pitched Blade Type (left) & Hydrofoil Type (Right)



(a) Small particles (5~10 um) (b) Large Particles (50~100um)

Fig. 6 Variation of number of small and large particles at each flocculator type

Rotating direction of the flocculator

To know the best-suited rotating direction of the flocculator in a water treatment plant (B-WTP) that vertical flocculator has been used, the characteristics of particle distribution was studied under two conditions of mixing the stirring direction of the flocculator with clockwise and counter clockwise, in each stage of flocculation part. Experimental conditions of 8 cases have been studied as shown in Table 1.

Table 1. Experimental Schedule to find the optimum rotational direction

Exp.#	Floc. #1	Floc. #2	Floc. #3	Remarks	Exp.#	Floc. #1	Floc. #2	Floc. #3	Remarks
1	CCW	CCW	CCW		**5**	CW	CCW	CW	
2	CCW	CCW	CW		**6**	CW	CCW	CCW	
3	CCW	CW	CCW		**7**	CW	CW	CCW	
4	CCW	CW	CW	**Current**	**8**	CW	CW	CW	**Best**

(CCW: Counter Clockwise, CW: Clockwise)

The distribution of the number of size particles have been studied at the outflow point of the first, second and third flocculation compartments. Fig. 7 shows the result of the eight studied cases. Analyzing the distribution of the small and big particles number showed that the CW, CW, CW direction in the three parts of the case #8 has the least number of small particles, which are good for the purpose of the flocculation process and the greatest in number of big particles. These results show that the efficiency without additional energy or cost could be enhanced, if the proper stirring direction of the flocculator has been decided.

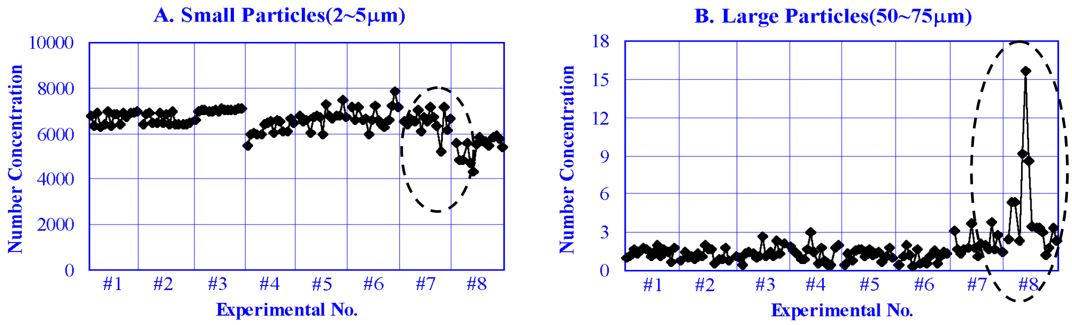


Fig. 7 Number of small and big particles at different experimental conditions

Analyzing the change of small and big particle number according to the flocculation process, the best-suited operation conditions can be decided according to the size of opening part, the direction and the form of the flocculator. In this method, the influence of the divided waterway length and the speed of optimizing flocculator can be decided (Han et al. [3]). Moreover, even though this result does not show quite big difference of efficiency in the measurement of remained turbid waves, the best-suited conditions can be definitely distinguished from the particle number. Therefore, the efficiency of the existing WTP by the facilities improvement of lower cost can be enhanced with knowing the optimizing operation conditions.

OPTIMIZING CASE OF SEDIMENTATION PROCESS

The schematic layout of sedimentation process is shown in Fig. 8. When flocs that were produced in the flocculation process flow to the sedimentation basin, they precipitate by the gravity. Therefore, the purpose of sedimentation process, when it measures at the same depth of water, is to reduce the number of the particle (not size). In addition, at the outflow point, the number of particle that flow out should be less without the particle size. According to this purpose, the way to enhance the efficiency through the diagnosis case and the best-suited operation conditions can be decided.

Influence of the Inlet Opening Size

In the sedimentation process, the inlet opening plays a role of stabilizing the current which flows from the flocculation basin. At this time, if the inlet opening size is not proper, flow can be unstable or flocs sometimes can be broken. Kawamura [4] reported that when the total opening size is around 6% of the Inlet Diffuser Wall cross section, break of flocs becomes the least and the flow becomes stable. In this experiment, the opening size was increased to 6.16% at the S-WTP, which had been 4.17%. Fig. 9 shows the measuring results of particles at 1 m (#2), 4 m (#3), 7 m (#4), and 26 m (#5) from the inlet opening under fixed depth of 2 m from the surface as shown in Fig. 8.

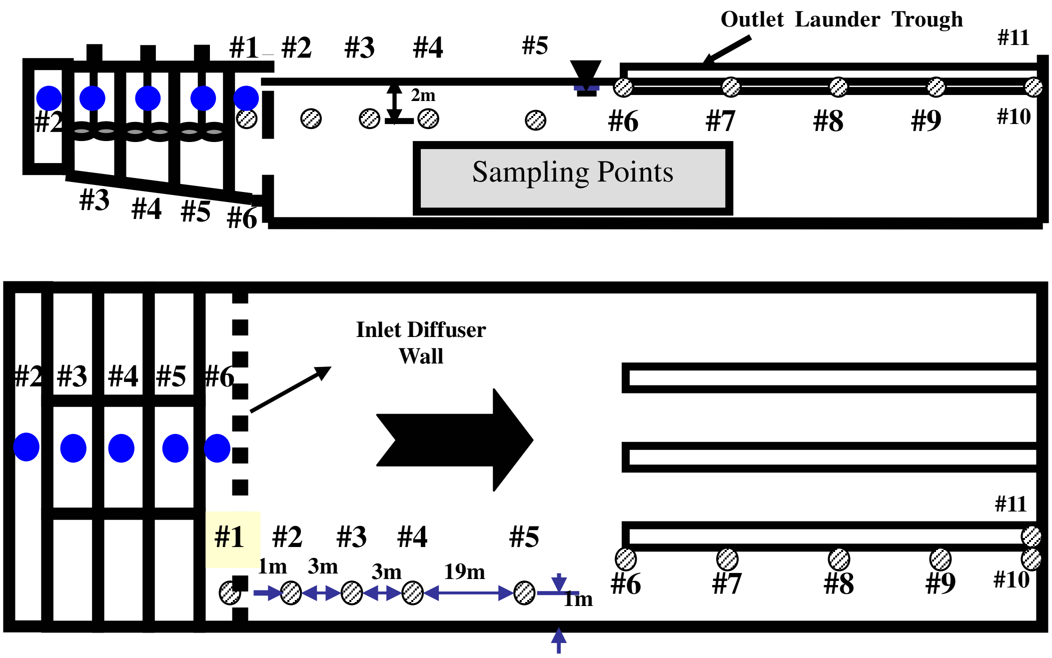


Fig. 8 The schematic layout of sedimentation process

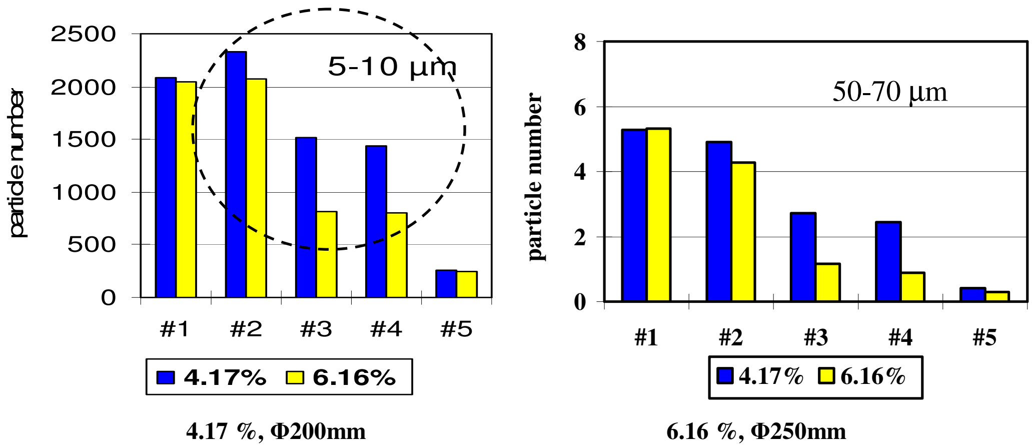


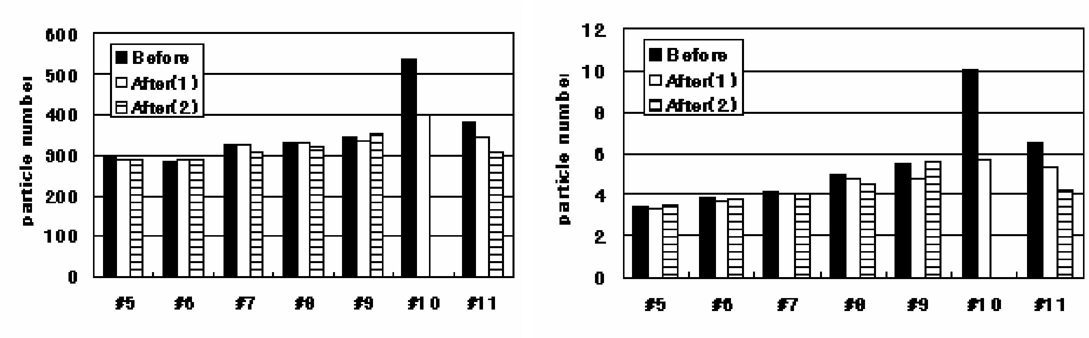
Fig. 9 Number of particles at each sampling points in sedimentation process

Analyzing the experimental results of Fig. 9, it can be noticed that the inlet opening size of 6.16% is proper for sedimentation process. Comparing to 4.17% case, the number of particles considerably decreased for all size of particles. For the 4.17% opening size, the number of the small particles was dramatically increased at #2, #3 and #4 points, and the break of flocs was found because of the narrow opening size. Therefore, expanding the opening size to 6.16%, the break of flocs was alleviated. The results were the same in the settled sludge interface analysing experiment.

Influence of the Density Current

One of the factors that are problematic in the sedimentation process is the influence of the density current due to the difference in temperature. The density current comes out when the difference in temperature is just 0.3 degree. Because of the narrow passing area, sludge that is precipitated is rising to the surface, so the number of particles was considerably increased. To avoid this phenomenon, installing the middle Diffuser Wall or lower the over- weir hydraulic loading rate could be suggested (AWWA [5]). Therefore, in this experiment, the best-suited method to avoid the influence of the density current was examined.

The density current is also generating in the understudy S-WTP. Because of this, the number of particles was considerably increased at the end part of the weir. In addition, it obstructs the efficiency. Therefore, in this experiment, the existing plant (Before) and additional installed case (After 1) which install weirs in the right and left sides to lower the over-weir loading rate were compared. Moreover, to exclude the particle that flows in from the end part of weir, blocking the end case (After 2), although it has high over-weir loading rate, was also compared. Figure 10 shows the analysis of the distribution of all flowed particles at sampling point #11 and about the particle distribution in each weir position at the measuring point of Fig. 8.



(a) 5 ~ 10 μm (b) 50 ~ 100 μm

Fig. 10 Variation of number of particles at each sampling points

From the results of Fig. 10, it can be noticed that, the particles number were considerably increased at the end part (#10) because of the influence of the density current in the existing weir (Before). In the additional installed case (After 1), the particles number of the end part were markedly decreased, and the total inflow particle number were also decreased. However, after 2 case, even though the over-weir loading rate became high, the inflow particle number does not increase at the #5~#9 point. Besides, the total inflow particles number (#11) shows remarkably lower than upper two cases because it closed the end part. Therefore, the particle increasing situation which is due to the density current can simply avoided by enclosing the weir end part over some degree of over-weir loading rate.

Scraper

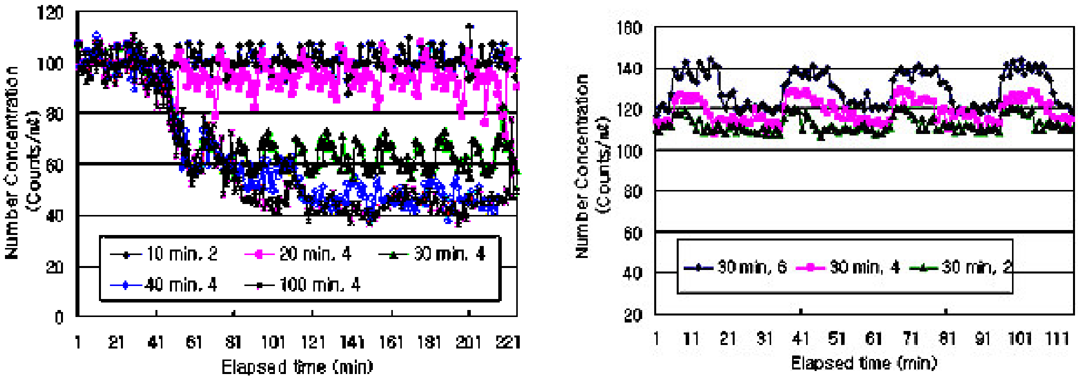
The scraper operation is the one of the factors that influences the efficiency of the sedimentation. As the movement speed or the period of scraper is fast, sometimes settled sludge is rising again. According to the literature, the proper movement speed was

0.2~0.5 m/min (Kawamura, [4]). Therefore, in this research, to examine the optimizing movement speed about the chain flight type scraper of the S WTP, the outflow particle was analyzed by changing the movement speed 0.2, 0.4, 0.6 m/min and making the operation time equal for 120min. The measuring point was #11 in Fig. 8. During the 0.4, 0.6 m/min speed, the outflow particle number was increased after the scraper operation. In the 0.4 m/min condition, 1~30 μm particles were increased in the outflow water after the scraper operation.

The maximum efficiency condition of sedimentation has achieved with 0.2 m/min speed of scraper for 60 min operation time and three operation times per day, which was higher than the existing condition of 0.4 m/min speed for 180 min operation time and the 4 operation times per day.

OPTIMIZING CASE OF THE DAF PLANT

Recently, to remove the difficult settling materials, the dissolved air floatation (DAF) plant was introducing. However, the operation condition that influences the total efficiency like scraper operation has not suggested yet. The operation condition that is used in the foreign country is applied to Korea. Therefore, in this experiment, the optimizing operation period and number of the scraper were decided in a DAF WTP. The measure was made at the outflow point of the DAF plant, and the measured result was shown in Fig. 12.



(a) Interval (b) Cycle

Fig. 12 Particle distribution of 5~10 ㎛

Figure 12 shows the change of the outflow water particle according to the periodical change of the scraper. The removal efficiency in the condition of the 4 times per 40 min and the 4 times per 100 min was higher than 2 times per 10 min because of the lower number of outflow particle. It is estimated that it could handle the shock because of the concentration of the scum. The same result also reported in the period of the Fig. 12 (b). That is, 2 times operation of the scraper generate the small number of outflow particle and have higher efficiency than 6 times or 4 times operation. According to this result, when reducing the period and number of the scraper, the removal efficiency is increased and the energy is reduced.

Using the particle counter, the optimizing operation condition of the scraper could be decided in the DAF plant. Moreover, as the depth measure of the bubble bed, which influences the efficiency of the DAF plant, became possible, the effect of the bubble bed in each operation condition could be easily measured. And the diagnosis about the proper angle of the baffle could be possible.

CONCLUSION

By using the particle counter, the correct facilities diagnosis could be done with optimizing operation condition in the various plants after the decision and the analysis about the particle movement which is proper to the purpose of each plant. As it is compared to the remained turbid waves, it has high sensitivity and is easy to measure. In the flocculation process, the diagnosis about the various facilities was possible. The efficiency through the facilities improvement could be increased, especially, for the rotating direction of the flocculator by only changing the rotating direction with putting the same energy.

In the sedimentation plant, the efficiency can be increased by changing the opening size of the inflow rectifying column, the preventive measure of the density current, and by lowering the movement speed, period, and the operation number of the scraper. In the DAF plant, the lower movement period and the operation number of the overworking scraper has increased the DAF efficiency.

Therefore, as deciding the proper facilities diagnosis and the operation condition about the existing plant, the efficiency can be increased as using the low-cost and the low-energy. In addition, it is reflected for the future design of the water treatment plant. Moreover, this measuring method could be applied to various facilities and the operation condition in each plant like optimizing flux condition and bubble layer depth of the DAF plant.

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