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A NEW SEWAGE TREATMENT SYSTEM WITH FLUIDIZED PELLET BED SEPARATOR

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ABSTRACT

A new sewage treatment system which is composed of a fluidized pellet bed separator, aerobic biological filter and micro-membrane filter was studied.

In the newly proposed system, at the first stage, higher molecular weight organic substances and suspended matter are removed by way of chemical coagulation and flocculation. For the operation, a new fluidized pellet bed separator with high separation rate of 200-300 m/day is introduced to improve the treatment rate. A large percentage of organic substances are removed by the new coagulation/flocculation process. Hence, the total BOD load to be applied to the following biological treatment becomes very low. In addition to this, the organic substances in the effluent from the fluidized pellet bed separator are only lower molecular weight substances which are easily biologically decomposed. Therefore easily decomposing and lower concentration pollutants enable use of a simple biological treatment process such as aerobic biological filter with as short a detention time as 1 hour. Finally, effluent from the biological filter is treated by a micro-membrane filter. By the membrane process, suspended matters in the biologically treated water can be removed completely. Phosphate concentration of the treated water is very low, which is caused by aluminum coagulation in the first step and biological intake of the nutrient in the second step followed by complete solid liquid separation in the third step.

KEYWORDS

Sewage treatment, Fluidized pellet bed separator, Biological filter, Micro-membrane filter, Coagulation, BOD removal, Phosphate removal

INTRODUCTION

A new sewage treatment system being proposed is schematically shown in Figure 1.

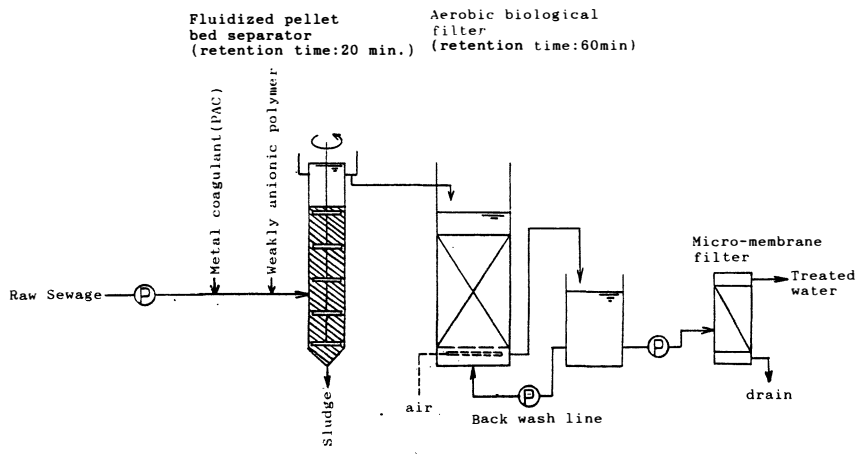

Fig. 1 Schematic diagram of New Sewage Treatment System

The process train is composed of a fluidized pellet bed separator, aerobic biological filter and micro-membrane filter.

In the first step of the treatment train, suspended matter and high molecular weight organic substances in raw sewage are coagulated by poly aluminum chloride (PAC) and weak anionic organic polymer, which are added at the inflow line.

A large percentage of suspended matter in raw sewage is organic substances. Coagulated floc of those organics by PAC is usually low density and fragile. By addition of a small amount of weak anionic polymer to these micro flocs, pellet like flocs, which have higher density and large diameter, are formed by a polymer bridged aggregation of micro flocs.

The pellet like flocs form a fluidized bed in a vertical separation column. The coagulated flocs are easily separated at short retention time of 10 to 20 min. in the fluidized pellet bed. Effluent from the top of the separator flows to an aerobic biological filter. In the fluidized bed separator, the height of pellet floc blanket zone is kept constant by a level controller, and surplus sludges are drawn out from the bottom. The value of effluent BOD from the fluidized separator is as low as about 30 mg/l. Hence, an aerobic biological filter with short retention time of 1 hour, can be applied to remove residual BOD to a satisfactory level. In this filter, lightweight aggregates whose diameters are between 5 and 10 mm, are used for biological filter media. Through this filter, the fluidized bed separator effluent flows downward with the filtration rate of 50 m/day. The organic matter which has lower molecular weight is removed by aerobic bio-reaction effectively in the filter bed.

In this system, effluent from the biological filter is finished by the hollow fiber micro-membrane filter. Suspended matter is removed completely through this process and BOD of the filtrate is less than 5 mg/l.

In this manner a new sewage treatment system which is composed of a fluidized pellet bed separator, biological filter and micro-membrane filter, remove BOD in a short retention time of about 1.5 hours, with a good effluent BOD concentration as low as 5 mg/l.

Additionally, in this system, a large percentage of phosphate is removed by chemical coagulation in the fluidized pellet bed separator and biological uptake as nutrients in the biological filter.

This system has been evaluated by pilot-scale experiment for long periods with successful performance and good stability in Sousei Sewage Treatment Plant, Sapporo, Japan.

EXPERIMENTAL PROCEDURES

A pilot scale experiment was conducted for evaluating a new sewage treatment system which is composed of fluidized pellet bed separator, aerobic biological filter and micro-membrane filter. The flow diagram of the experimental plant is shown in Figure 1, and the operation condition is listed in Table 1.

Table 1. Operation condition

Process	Operation condition
Fluidized Pellet Bed Separator	Up-flow fluidized bed separator Up-flow velocity 200 ~ 300 m/day Coagulant dosed PAC 10 ~ 15 mg as Al_2O_3/l Weak anionic polymer 1.5 mg/l
Aerobic Biological Filter	Down flow reactor(two filters in series) Filter media: ϕ5 ~ 20 mm light weight aggregate Bed depth : 1,200mm+1,000mm Space velocity Dec. 20, 1990 ~ Feb. 15, 1991, S.V. =0.4hr^{-1} Feb. 15, 1991 ~ Oct. 31, 1991, S.V. =1 hr^{-1}
Micro-membrane Filter	Hollow fiber membrane Rejection size : 0.2μm Flow : Dead end Flux : 2.5 m/day Pressure loss : 20 ~ 100 kPa

EXPERIMENTAL RESULTS

Average water quality of effluents from each step in the pilot-scale experiment, are listed in Table 2.

Table 2. Water quality of pilot plant

	Raw sewage	Effluent of Pellet bed Separator	Effluent of Biological Filter	Effluent of Micro-membrane Filter
Turbidity(NTU)	103.1	9.6	1.43	.03
SS (mg/l)	146.1	13.8	1.92	-
BOD (mg/l)	139.5	29.8	4.66	1.94
CODcr(mg/l)	283.8	73.9	36.5	25.0
Ort-P(mg/l)	1.80	.104	.012	.005

Note:

1. The values in the table are averages from Feb. 1, 1991 to Oct. 31, 1991.
2. BOD of the biological filtrate is ATU-BOD

Seasonal variation of SS, BOD and Ort-phosphate removal is shown in Figure 2, 3, 4.

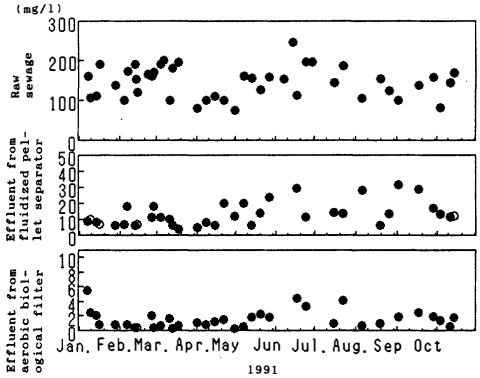

Fig. 2 Removal of SS

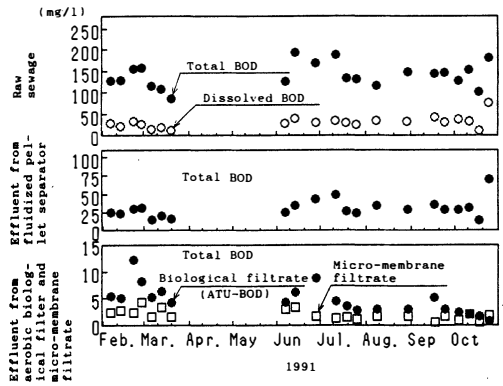

Fig. 3 Removal of BOD

BOD REMOVAL

Experimental results show that 79 % of BOD in raw sewage were removed by the pellet bed separator.

As shown in Figure 5, BOD concentration of effluent from the separator was about 90 % of dissolved BOD existing in raw sewage.

Almost all suspended BOD and 10 % of dissolved BOD existing in the raw sewage were removed by the fluidized pellet bed.

Similarly, almost all suspended CODcr and 30 % of dissolved CODcr in the raw sewage were removed, and removal rate of CODcr was about 73 % in this separator.

As a result, a large amount of organic matter in the raw sewage was removed by the pellet bed separator, so that the loading of organic matter to the biological filter reduced greatly. Hence, the retention time of biological treatment can be as short as 1 hour and

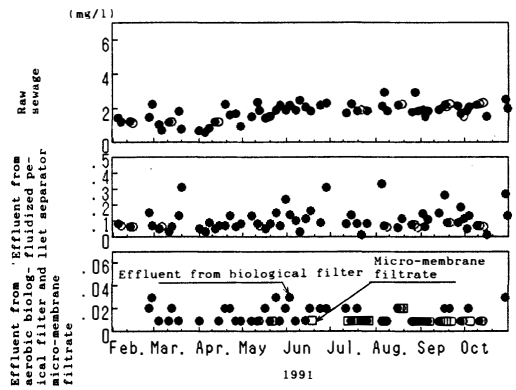

Fig. 4 Removal of Ort-phosphate

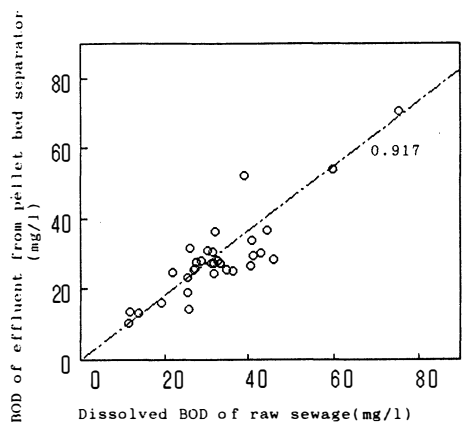

Fig. 5 Relationship between BOD of effluent from pellet bed separator and dissolved BOD of raw sewage (dissolved is GFB filtrate)

low BOD effluent about 5 mg/l is obtainable.

As shown in Figure 6, the relationship between BOD concentration of effluent from the biological filter and BOD volumetric loading, was almost equal to that of the ordinary biological filter which treated the effluent from primary sedimentation in sewage treatment. So, effective performance of biological filter in spite of short retention time was considered to be due to the large reduction of BOD in pellet bed separator.

The relationship between BOD of the micro-membrane filtrate and the filtrate from biological filter is shown in Figure 7. In micro-membrane filtration, suspended BOD was removed completely, and BOD removal rate was about 60 %. As a result, BOD of raw sewage could be reduced by this system to less than 5 mg/l with short retention time of 1.5 hours.

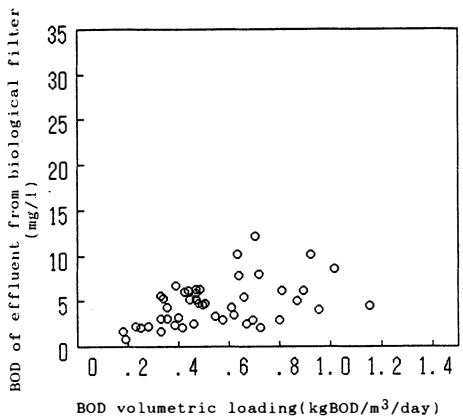

Fig. 6 Relationship between BOD concentration of effluent from aerobic biological filter and BOD volumetric loading

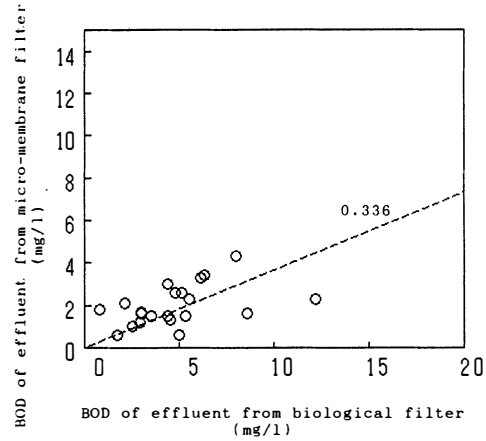

Fig. 7 Relationship between BOD of effluent from micro-membrane filter and that from biological filter

PHOSPHATE REMOVAL

Experimental results show that about 96 % of Ort-phosphate was removed by pellet bed separator. In this process, phosphate was removed through the precipitaion with metal coagulant. In this study, poly-aluminum chloride(PAC) was used as metal coagulant. The relationship between Ort-phosphate concentration of the effluent from pellet bed separator and the ratio of added aluminum mole concentration to Ort-phosphate mole concentration in raw sewage is shown in Figure 8. The relationship is nearly the same as that of tertiary phosphate removal by ordinary coagulation process.

Effluent from the pellet bed separator, which has about 1 mg/l of Ort-phosphate concentration, flowed into the aerobic biological filter. In the biological filter, Ort-phosphate was taken up by microorganisms as nutrient. The amount of Ort-Phosphate removal by biological filter was nearly proportional to the amount of BOD removal, as shown in Figure 9. The ratio of the Ort-phosphate removal to BOD removal was as small as about 0.002, but biological process was not restrained.

Total Phosphate(T-P) concentrations of each effluent are listed in Table 3.

Table 3. Total phosphate concentration of each process effluent(mg/l)
average value of 4 times measurements
Al/T-P(mole ratio)=1.61 ～ 2.62

	Raw Sewage	Effluent of Pellet Bed separator	Effluent of Biological Filter	Effluent of Micro-membrane Filter
Total	4.82	0.175	0.0338	0.0151
Dissolved	1.78	0.084	0.0142	0.0151
Suspended	3.04	0.0905	0.0196	–

Note: Dissolved is 0.45 μm membrane filtrate
Dissolved T-P of biological filter effluent and T-P of micro-membrane filter were measured after concentrating about 20 times.

In this list, dissolved and suspended matter are divided by 0.45 μm membrane filtration. In raw sewage, about 50 % of total phosphate were suspended, and these were almost removed by pellet bed separator.

Furthermore, dissolved phosphate was also removed by chemical coagulation by PAC. Hence, 96 % of total phosphate in raw sewage was removed by the pellet bed separator. Additionally, in the following biological filter, 2.9 % of total phosphate were removed, and 0.4 % were removed by the micro-membrane filtration.

In the micro-membrane filtration, suspended phosphates which were considered to be contained in microorganisms, were removed. In this system, removal rate of total phosphate reached as high as about 99.8 %.

In addition to the above mentioned removability, phosphate elution from the sludge of pellet bed separator was examined by periodical measurement of the supernatant of sludge receiving tank.

The results of the elution examination are shown in Figure 10.

Ort-phosphate concentration

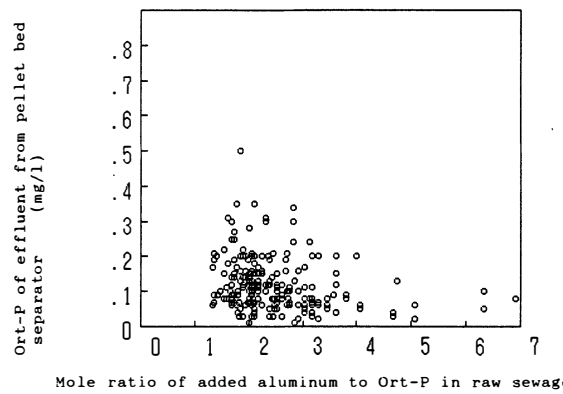

Fig. 8 Relationship between Ort-phosphate concentration of effluent from pellet bed separator and mole ratio of added aluminum to Ort-phosphate in raw sewage

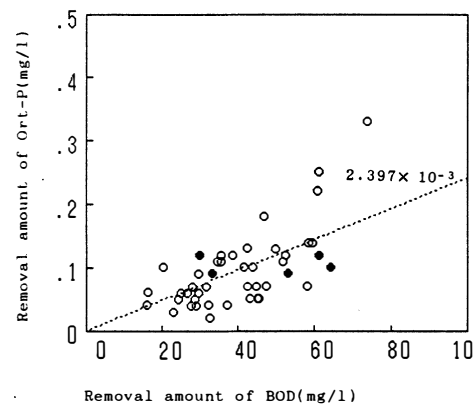

Fig. 9 Relationship between BOD removal and that of Ort-phosphate in aerobic biological filter

of supernatant was always less than 0.2 mg/l, for 50 days. Almost no phosphate elution from these sludges occurred.

In conclusion, phosphate in raw sewage was highly removed by this system, to a concentration of less than 0.1 mg/l.

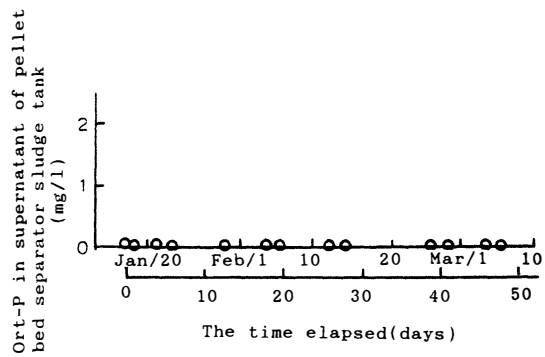

Fig. 10 Phosphate elution from sludge of pellet bed separator

GEL CHROMATOGRAPHIC STUDY

Sepadex G-15 gelchromatograms of each process effluent (0.45μm passed) are shown in Figure 11.

High molecular weight constituents of raw sewage which appeared in fraction No 16 (i.e. $\geqq$1500), were removed by fluidized pellet bed separator.

In the gel chromatogram of biologically treated water, high molecular weight constituents which appeared around fraction No 16, showed relatively high adsorbance in 260nm, and, hence, it seems organic matter of that treated water was relatively biologically stable.

The new sewage system is able to convert biodegradable organic matter in raw sewage to stable matter, as well as to reduce BOD with high percentage removal in a short retention time of about 1.5 hours.

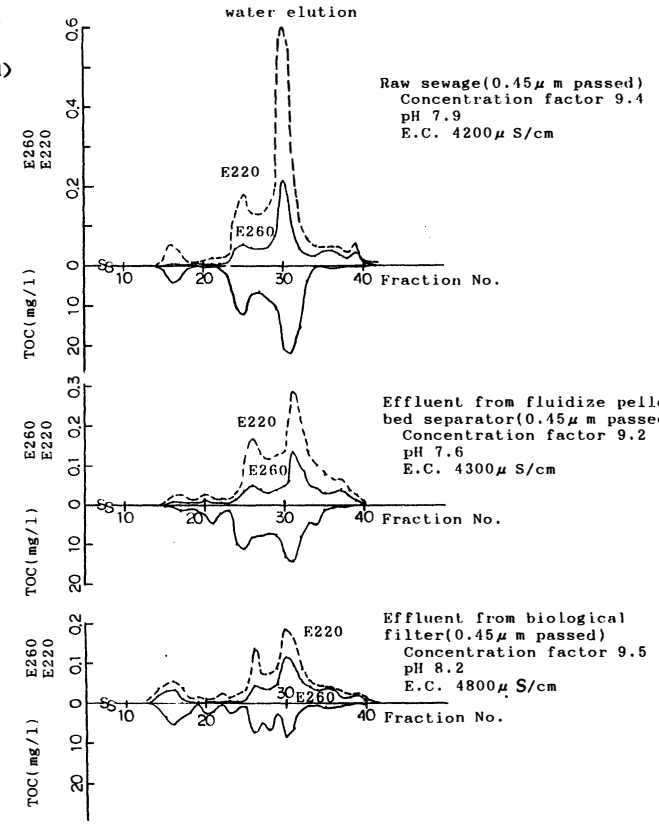

Fig. 11 Organics removal evaluated on Gel chromatogram
Column: 2.5×90cm Sephadex G-15
Fraction volume 10ml

SUMMARY

Using poly-aluminum chloride 10—15 mg as Al_2O_3/l and weakly anionic polymer as little as 1—2 mg/l, the new sewage system with a retention time of as short as about 1.5 hours can remove phosphate and BOD with high efficiency.

(1) In the fluidized pellet bed separator, phosphate and suspended solid in raw water were removed in about 20 min. No phosphate elution from sludge of this separator was observed.

(2) By removing suspended BOD in the pellet bed separator, the BOD load to the following biological reactor reduced both quantitatively and qualitatively. The biological filter followed removed BOD in short retention time in 1 hour. Phosphate was also removed as nutrients for microorganisms.

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