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AN IMPROVED TREATMENT OF ANIMAL WASTEWATER

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ABSTRACT

The purpose of this study is to examine the purification efficiency of the septic tank method which has been applied by the most of Korean livestock farms, in terms of anaerobic and aerobic treatment.

Except several days in summer, BOD of effluent shows 1,500-3,000 ppm by anaerobic process. In most cases, it exceeds the legal permitted standard of 1,500 ppm. The total nitrogen contents according to the seasons show an increase by decrease of temperature. The removal effect on T-N is hardly found. The suspended solids contents of effluent are reduced to the level of 50-90 %.

Although BOD contents of effluent are kept high in the beginning, the removal rate of BOD shows 80 percent in the latter half by the aerobic treatment. The removal efficiency of total nitrogen does not appear through the experimental period, but the contents of T-N are not increased in the aerobic process unlike in the anaerobic process. The total phosphorus contents in effluent keep a constant level of 14 mg/L in average. The removal rate of phosphorus shows 91 percent in the last stage.

Key Word : Purification, Animal Wastewater, Septic Tank, BOD

INTRODUCTION

As the consumer's income is boosted, animal protein demand is upheaved. In order to meet these needs, the number of livestock raised has been increased yearly as shown in table 1.

Therefore, a lot of animal waste has been produced and the environmental pollution through the animal waste becomes a serious problem, and it is necessary to take proper measures. In 1991 Korean government reorganized the laws and regulations related with environmental preservation. The contents of the revised regulations are summarized in table 2. The allowable BOD contents for those farms which need to get permission for their farming from the authority range from 30 to 150 ppm and for those farms which need to notify their farming plan to the authority below 1,500 ppm.

In a survey about wastewater treatment adopted by the farms which were legally controlled, it shows that the septic tanks method is widely applied in cattle and swine farms by 48.1 percent (Ministry of Environment 1990). The Korean government has also recommended the small and middle size farms to apply this method. The septic tank method consists of primary chamber, 1st and 2nd Digester, and a sedimentation tank (Fig. 1).

In the septic tank, a fermentation is followed by the anaerobic process. It was known that this purification method is usually applied for the wastewater which has relatively low pollutants and also this method is good when a large quantity of water has to be treated, but its efficiency is relatively low.

The animal wastewater includes urine, barn cleaning water and flowing water by drinking, dung and feeds rest, etc. So it shows a high level of organic contaminants. But there is no empirical data how efficient this method is in purifying the animal wastewater. In this context, the purpose of this paper is aiming at analysing whether this method is applicable for treatment of the animal wastewater which has relatively high level of contaminants. In addition, this paper is trying to know whether aerobic process applied in this system is effective in purification.

MATERIALS AND METHOD

For the anaerobic test, two swine farms are selected from Chungju area. They have established the septic tanks according to the standard plan suggested by Ministry of Environment of Korea.

Farm A is raising 80 heads of sows heavily depending on purchased feed without crop farming. Dung is piled up in the compost barn and traders use it for free. The wastewater flows out after the anaerobic treatment in septic tank. This farm has a digester of which capacity is 160 m^3 and a settling tank of which capacity is 40 m^3.

Farm B is operating a complex farm of apple orchard with 50 heads of sows. The dung from the stall is mixed with the rice hulls and used as a compost for the self-use in orchard after the decaying process in the pile. The animal wastewater in the septic tank is not used as a liquified fertilizer and flows out into the sewer. The capacity of septic tanks of this farm is 80 m^3 of digester and 20 m^3 of sedimentation tank.

For the aerobic test in the farm A, a roots blower (model S65) is installed in the 2nd digester of septic tank. The electric capacity of motor is 3.7 kW and it supplies air by 2.46 m^3/min. The injected air by the blower reaches to the diffusers through the pipeline installed in 3 rows on the bottom of aeration tank. Each row has 7 bowl type of diffusers (BS-100) and from there the air is dispersed. The diffuser has a rubber valve inside, so that it prevents the wastewater from flowing backwardly, when the blower stops. The fig. 2 shows the layout of aeration tank installed with diffusers. The wastewater flows continuously in this system, and the air is supplied three times per day, and 6 hours per each time (Fig. 3).

A thermometer model AM-7001(Anritsu) is used to measure the temperature in the 2nd digester (aeration tank). During the aeration, bubbles are made, so antibubbling system is deviced.

For the purpose of analysing, the samples are gathered from the primary chamber, the second digester and drainage hole. In order to know the degree of the purification, BOD, pH, total nitrogen, nitrogen compounds, SS, phosphorus etc. are analysed.

To design the wastewater treatment facility, it is desirable to know the amount of wastewater in the livestock farm. The amount of daily excretion of animals can be found in the literature. However, the amount of wastewater becomes increased because of addition of water used for barn cleaning and the flowed water by drinking. And the amount of wastewater may depend on the raising method. In a typical farm with 80 sows, the amount of animal wastewater is measured on March '92 to be 2.4 m^3/day by accumulation method (Maeng et al. 1992). If it is divided by the raising number, daily wastewater will be about 30 liters per sow.

RESULTS AND DISCUSSION

ANAEROBIC TREATMENT

Sometimes the BOD contents of the influent is over 5,000 ppm, but it ranges from 2,000 to 3,000 ppm. The pH-value shows from 7.0 to 9.0, but it goes down to 6.0 on December. This causes in accumulation of reaction matters because of slowness of reaction speed.

The BOD contents of effluent and variation of temperature related to seasons are shown in figure 4. The temperature in 2nd digester is 20-25°C in summer days, 13-15°C in autumn, and 4-5°C in winter season. The BOD-contents of effluent indicating the decomposition degree of organic matter are decreasing, as the temperature is lowered. It is caused by withering of microorganism's activity in lower temperature. The BOD contents in farm B show relatively high and it results in the reduction of decomposition capability because of small tank's capacity comparing with the raising number of hogs. The BOD reduction rate is 28-67% in summer days, 17-40% in fall and 12-33% in winter season. As shown in the figure 4, in every case it exceeds the legally permitted standard of 1,500 ppm. Therefore, it can be pointed out as serious problem that the efficiency of this method is comparatively low.

Fig. 5 and 6 show the SS (suspended solid) and the total nitrogen contents. The SS-contents are decreased by a certain reduction rate from 50 to 90% because of settling effect. Such a difference by the season is caused by the effect of the amount of wastewater difference.

The content of total nitrogen increases by season from summer to winter. It is caused by the slow chemical reaction due to the reduction of temperature and by the variation of concentration of wastewater seasonably. An analysis for the nitrogen compounds could not be undertaken. Therefore, more detailed explanation is limitted. Except the 35 percent reduction rate in farm A in summer, the reduction of nitrogen did hardly follow. As a result, with only anaerobic treatment the effective nitrogen reduction can not be expected.

AEROBIC TREATMENT

The BOD contents of influent from the primary chamber vary widely. It depends on the rainfall or barn cleaning water, but it is 3,400 ppm in average. The effect of BOD reduction by aerobic process is shown in figure 7.

Although BOD contents of effluent are kept high in the early stage, the removal rate of BOD shows 80% in the latter half of winter season after gradual stabilization. In the early stage, the activated sludge was not formed enough to decompose organic matter. But the effect of purification was appeared gradually with the accumulation of the activated sludge. However, the lower efficiency of purification is attributed to the fact that the activity of microorganism was not in optimum condition by lowered temperature. Besides, the sedimentation tank of septic tank used in the system is not optimal, since the bottom is not suitable to settle the sludge, and it is hardly possible to return the sludge to the aeration tank. The temperature of aeration tank decreases from 16°C to 11°C in the experiment period.

The variation of total nitrogen contents in influent is affected by the outside factors. The total nitrogen contents show high level in influent as well as in effluent. The reduction effect of total nitrogen could not be seen through the experiment period, but in the last stage the reduction rate shows 63 percent showing 935 mg/L in effluent of total nitrogen in comparing with the 2,509 mg/L in influent (Fig. 8). The ammonia nitrogen (NH_4-N) contents in effluent are so high that it takes over 70 percent in average in total nitrogen. It's value is constant all over the experiment period. Though an oxidation of NH_4-N by the aeration could be expected, such a tendency could not be seen. The contents of NO_3-N cover 7 percent among the total nitrogen in effluent and a trace of nitrite can be found. Generally, the reaction of denitrification could not be done thoroughly.

The variation of phosphorus contents in wastewater is shown in figure 9. Although the phosphorus content in influent is varied by the factors outside, that in effluent keeps a constant level. In the last stage the reduction rate of phosphorus shows 91 percent. Generally, it shows a good result and the phosphorus content in effluent is 14 mg/L in average.

The electrical capacity used in the period is 54 kWh per day in average. Applying the price of electricity for agricultural purpose, it costs 2,000 won (US$ 2.5) per day amounting to about 60,000 won (US$ 75) per month.

DEVELOPMENT OF MODEL PLANT

A test is done by the system with a sedimentation tank, which enables the sludge to be settled and to return it to the aeration tank. The goal of purifiçation efficiency of wastewater is over 90 percent of BOD reduction and this system has a spare capacity in case of extending the raising scale.

Figure 10 shows the plan of model. The long time aeration activated sludge system is chosen in this system, and design parameters and specifications are followed in table 3 and 4.

Since the construction of standard activated sludge process costs too much, this system has inserted aeration process and the settling of sludge to the septic tank method. In order to comply with strict regulation in the future, it is desirable to keep the BOD contents of effluent to be under 170mg/L. The data obtained from the test is shown in table 5.

In order to measure BOD contents in influent, a sample is taken from the water after screened. Since the experiment facilities was somewhat wrong at the beginning, the BOD of the effluent was relatively high. That is, where the wastewater flew into the aeration tank, it run batch system, and where the wastewater flew out to settling tank, it run continuously. As a result, unpurified wastewater flew directly into the settling tank. Recently this operation error is corrected, the whole system runs through the continuous type. The BOD in effluent shows 117 mg/L, and SS 72 mg/L showing good results.

The building cost amounts to about 36 mill. won (US$ 45,000). It is more than that of septic tank, but the purification efficiency is better than septic tank. This system has the BOD load capacity from 0.2 $kg/m^3 \cdot day$ so that it has a room for overload or in case of extension of farm size. It can be recommended to the livestock farms as a model plant.

CONCLUSIONS

The purification efficiency by septic tank method is investigated from the view point of anaerobic, aerobic process, and a new system is developed. The removal rate of BOD shows 28-67% in summer days, 17-40% in fall and 12-23% in winter season by anaerobic process. The BOD contents of effluent range from 1,500 to 3,000 ppm. Except several days in high summer, it exceeds the legal allowable standard which is 1,500 ppm.

Total nitrogen contents are increased, as the temperature decreased. The removal effect could hardly be seen except in summer days. The SS contents vary by the seasons, the SS contents in influent are decreased by the rate of 50-90 percent, when it is compared with that of influent.

In the test of aeration, the BOD contents in effluent are appeared from high level to the low. The removal rate of BOD shows 80 percent in winter season. The removal effect of total nitrogen can hardly be found. Ammonia nitrogen (NH_4-N) contents are relatively high and it occupies 70 percent in average out of the total nitrogen in effluent. Nitrate (NO_3-N) contents cover 7 percent in average and a trace of nitrite can be found. The phosphorus contents in effluent show constant level of 14 mg/L in average. In the last stage, the removal rate from phosphorus shows 91 percent.

A system is designed to settle the sludge and to return it to the aeration tank. After an operation of a long time aeration activated sludge process, the BOD load capacity shows 0.2 kg/m^3/day and the goal of BOD contents in effluent is lowered to 170 mg/L. As a temporary results, the BOD in effluent is 117 mg/L and SS 72 mg/L respectively. It is desirable to recommend livestock farms to apply this model system.

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Table 1. Development of Korean livestock (Unit : 1,000 head)

	1970	1980	1990	2000*
Korean cattle	1,286	1,472	1,622	2,015
Dairy cattle	24	207	504	638
Hogs	1,126	1,784	4,528	8,705
Poultry	23,633	40,130	61,689	95,298

Source : National Livestock Co-operatives Federation

* : Estimated

Table 2. Regulation of farm size based on building area

	Permission*	Notification
Hog	over 1,400 m^2	over 250 m^2, under 1,400 m^2
Cow, Horse	over 1,200 m^2	over 350 m^2, under 1,200 m^2
Poultry, Sheep	-	over 350 m^2

* : The figure shall be half of this in the specially controlled area for drinking water preservation.

Table 5. BOD removal in aerobic treatment (mg/L)

Date	Item	Influent	Effluent	Removal rate
11/20	BOD	1,543	600	61%
	SS	698	454	35%
1/18	BOD	629	117	81%
	SS	580	72	88%

Table 3. Design parameters of activated sludge process

Farm size : cow 50 heads and sow 20 heads(=swine fattening 200heads)
Feedstuffs : concentrates, roughage and purchased feed
Amount of excretion : cow 50 L/head/day x 50 heads = 2.5 m^3/day
Loading : BOD = 0.8 kg/head/day x 50 heads = 40 kg/day
SS = 3.7 kg/head/day x 50 heads = 185 kg/day
Amount of excretion : hog 5.4 L/head/day x 200 heads = 1.08 m^3/day
Loading : BOD = 0.43 kg/head/day x 200 heads = 26 kg/day
SS = 0.43 kg/head/day x 200 heads = 86 kg/day
Barn cleaning method : dung removal rate 90% (water flushing)
Amount of excretion: cow 23 L/head/day x 50 heads = 1.15 m^3/day
hog 3.69 L/head/day x 200 heads = 0.738 m^3/day

total 1.888 m^3/day
Loading after dung removal :
cow BOD = 0.152 kg/head/day x 50 heads = 7.6 kg/day
SS = 0.460 kg/head/day x 50 heads = 23 kg/day
hog BOD = 0.029 kg/head/day x 200 heads = 5.8 kg/day
SS = 0.058 kg/head/day x 200 heads = 11.6 kg/day
total BOD = 7.6 kg/day + 5.8 kg/day = 13.4 kg/day
SS = 23 kg/day + 11.6 kg/day = 34.6 kg/day
Amount of wastewater : cow 80 L/head/day x 50 heads = 4 m^3/day
hog 15 L/head/day x 200 heads = 3 m^3/day

total 7 m^3/day
Concentration : BOD = 13.4 kg/day ÷ 7 m^3/day = 1900 mg/L
SS = 34.6 kg/day ÷ 7 m^3/day = 4900 mg/L
Goal purification : BOD below 170 mg/L
SS below 390 mg/L

Table 4. Specification of activated sludge process

(a) Sand settling tank

$7\ m^3 \div 1$ hour x 5 min. ÷ 60 min/hour = $0.6\ m^3$

(b) Screen

Decline angle 60 °

Removal rate : BOD 10%, SS 20%

Loading : BOD = 13.4 kg/day x (1-0.1) = 12.1 kg/day

SS = 34.6 kg/day x (1-0.2) = 27.7 kg/day

Concentration : BOD = 12.1 kg/day ÷ 7 m^3/day = 1700 mg/L

SS = 27.7 kg/day ÷ 7 m^3/day = 3900 mg/L

(c) Water collecting tank

Amount of 1 day wastewater : 7 m^3

(d) Aeration tank

Capacity 60m^3 (BOD load 0.2 kg/m^3/day)

MLSS 4,000 mg/L (4 kg/m^3)

BOD-SS load 0.05 kg/SS kg/day{=12.1 kg/day ÷ (4 kg/m^3x 60m^3)}

Aeration time (retention time) : 200 hours {= 60 ÷ (7 ÷ 24)}

Aeration intencity 2.4 m^3/m^3/hour

Amount of return sludge :

$MLSS = \{(Q_1 \times S_1) + (Q_2 \times S_2)\} \div (Q_1 + Q_2)$

$Q_2 = 0.12\ m^3/day$

Return sludge rate : 0.12 ÷ 7 x 100 = 2 %

Excess sludge :

$\triangle SS = a \times RBOD - b \times V \times MLVSS + RSS$

a = 0.5

RBOD = 0.9 x 12.1 kg/day (removal rate 90%)

b = 0.07

V = 60 m^3

MLVSS = 0.8 x 4 kg/m^3 (usually 80%)

RSS = 0.9 x 27.7 kg/日 (removal rate 90%)

$\triangle SS$ = 17 kg/day -------> 1.7 m^3/day

Purification effect :

water quality BOD = 1,700mg/L x (1-0.9) = 170 mg/L

SS = 3,900mg/L x (1-0.9) = 390 mg/L

(e) Sedimentation tank

Settling time over 3 hours

Capacity 7 m^3/day

(f) Sludge tank

25 m^3 (25 ÷ 1.7 = 15 day)

(g) Disinfection

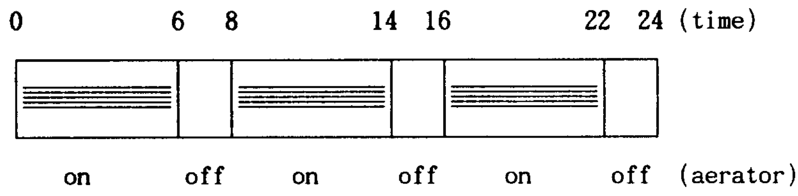

Fig. 3. Time chart of experimental operation

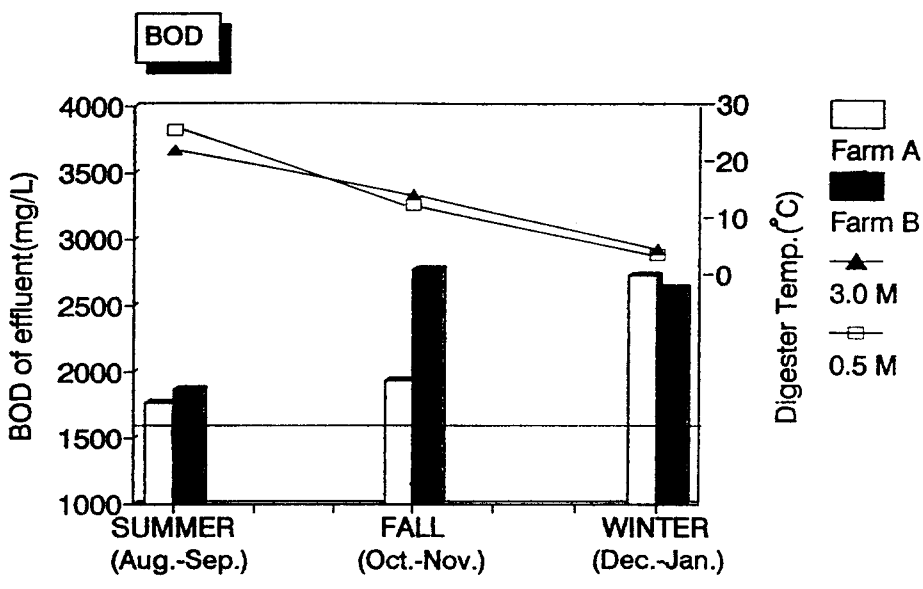

Fig. 4. Effect of digester temperature on the BOD of effluent.

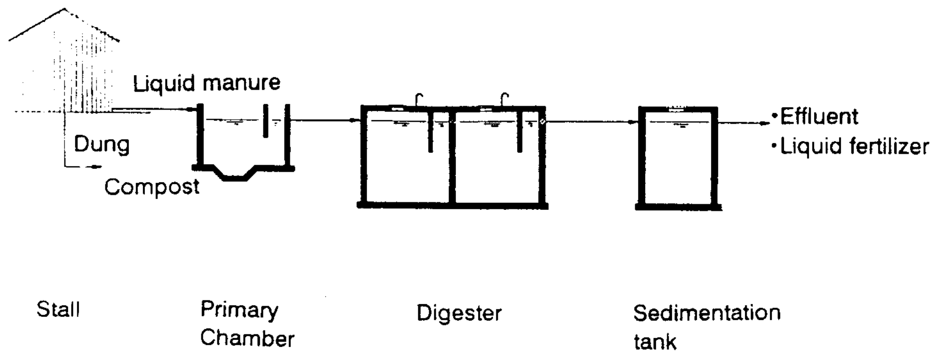

Fig. 1. Flowsheet of septic tanks.

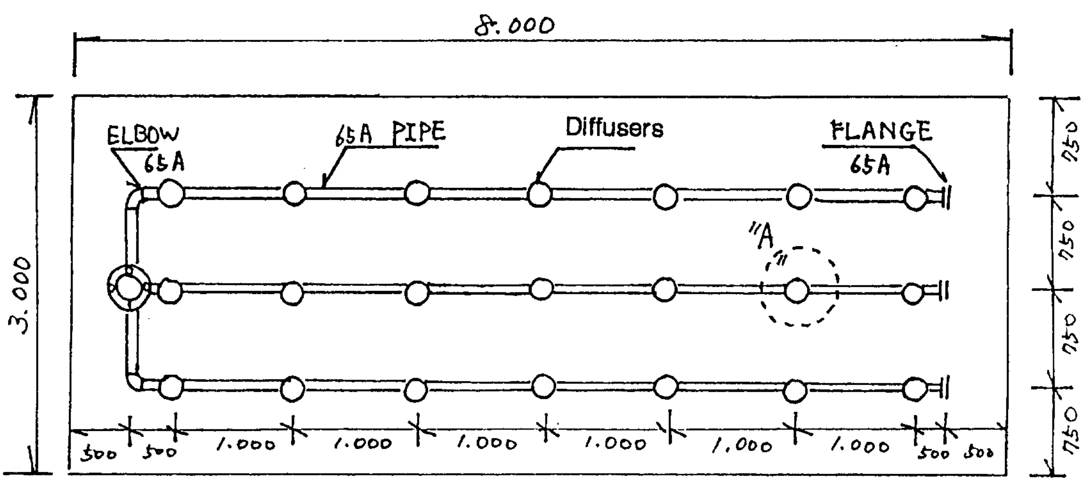

Fig. 2. Disposition diffusers in aeration tank.

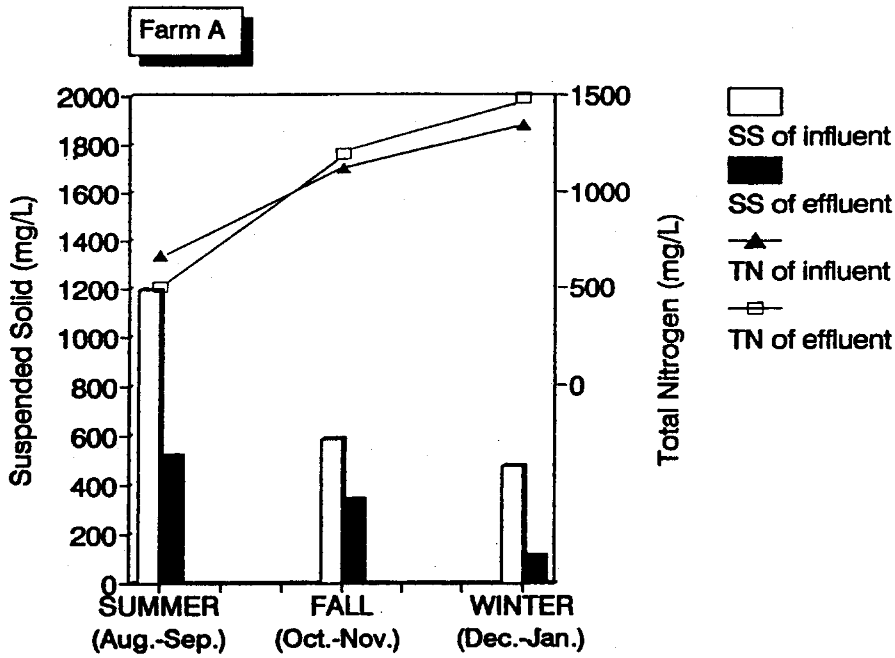

Fig. 5. Changes of SS and T-N contents by season in farm A.

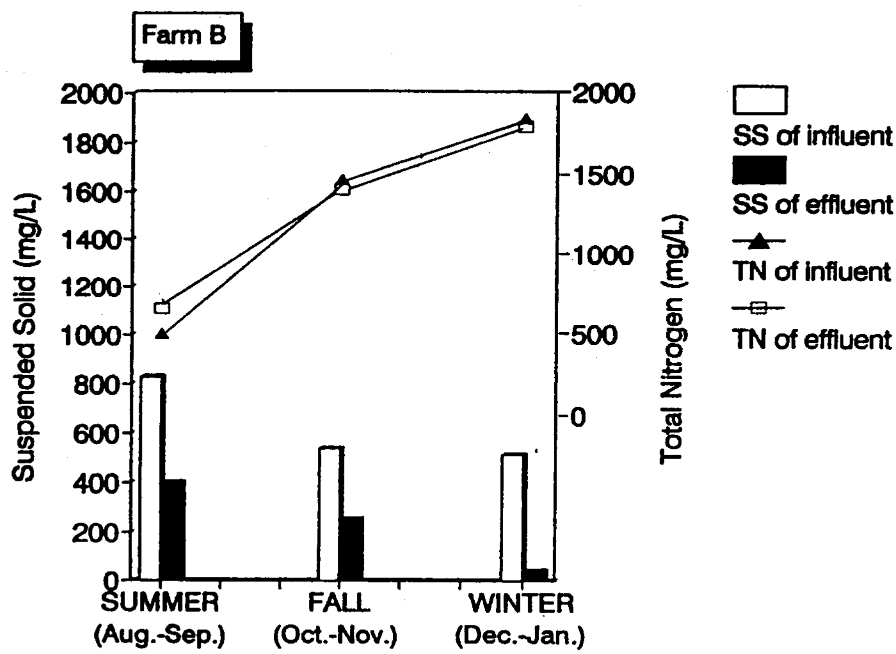

Fig. 6. Changes of SS and T-N contents by season in farm B.

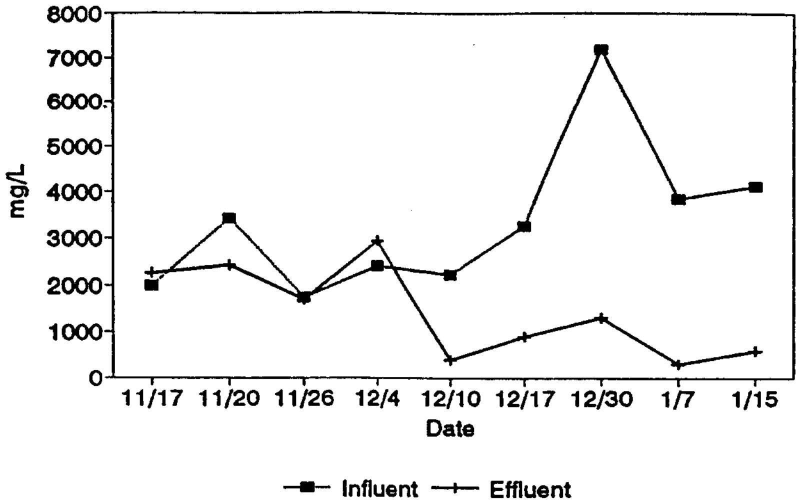

Fig. 7. BOD removal in aerobic treatment.

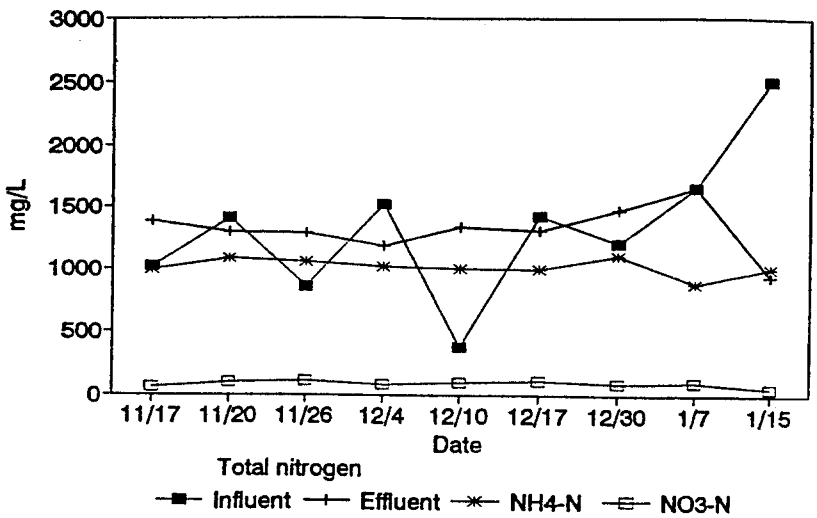

Fig. 8. Variation of total nitrogen and NH4-N, NO3-N concents in effluent.

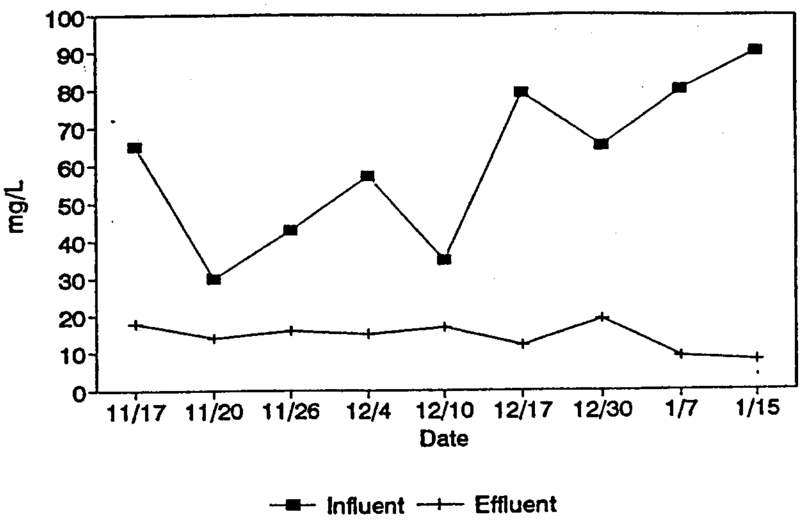

Fig. 9. Change of total phosphorus.

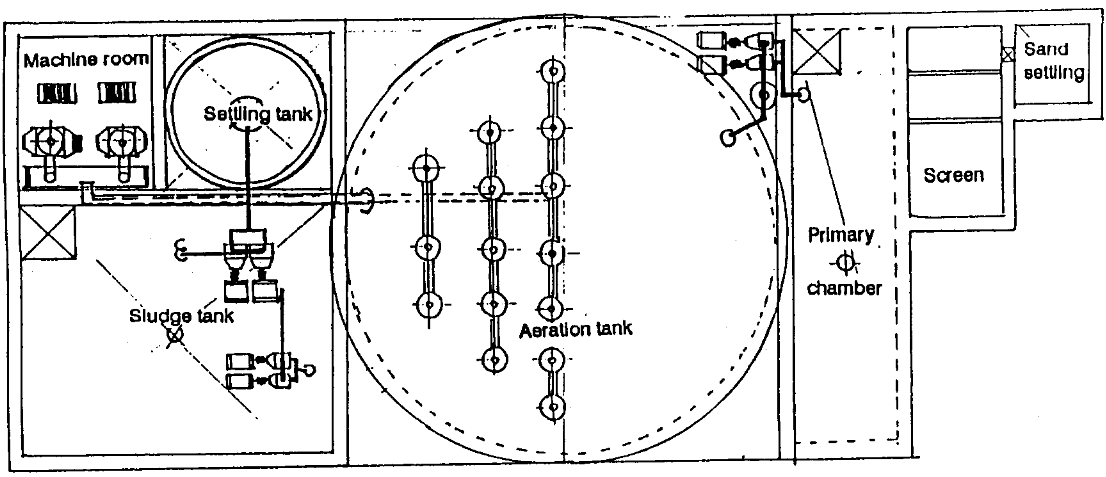

Fig. 10. Plan of activated sludge system.