Study on the Systematic Technology of Promoting Purification for the Livestock Wastewater and Reuse

Yoshiichi OKADA†, Jae-Do SHIM†, Masahumi MITARAI†
Takayuki KOJIMA*, Yoshinori GEJIMA†

†Dept. of Agricultural and Forest Science, Fac. of Agriculture, Miyazaki Univ., Miyazaki 889-21, Japan
*Dept. of Agricultural Science, Fac. of Agriculture, Saga Univ., Saga 840, Japan

ABSTRACT

The objective of this study is to develop a systematic purification plant using the metabolism of aerobic microorganisms. This system is subsequently aerated and continuously removes suspended solids and settling sludges caused by aerating pressure at the bottom of a lower pipe (i.e.,Continuous Removal of Suspended solids and Settling sludges,CRSS).

The CRSS plants are brought out by introducing fine air bubbles into the liquid phase of a lower pipe in the bio-reactor. These plant uses aeration pipe, with multiple inlets to sweep the floor of bio-reactor tank, instead of the conventional scraper mechanisms. The principal advantage of this system is that it can continuously remove very small or light particles that settles completely within a short time. Once the particles have been floated to the surface, they can be moved into the pipe and collected in the settling tank by sequently aerated pressure.

The experimental results shows that about 99.0% of the biochemical oxygen demand(BOD), 99.3% of the suspended solid(SS), 92.3% of the total nitrogen(T-N), 99.0% of the turbidity(TU), 100% of the total coliform(TC)and ammonia was respectively removed during aerobic digestion for 9 days.

These result indicates that the CRSS plants are very effective for reduction and deodorization of swine wastewater contaminants, and the efflux from CRSS can either be discharged in the river or used as nutrient solution of formulation for plant growth factories. The developed CRSS plant proved to be flexible and it can simply be adapted to any type of biological waste treatment problem.

Key Word : CRSS, Intensive aeration, Aeration pipe, bubble transfer, Circulating treatment, microorganism, coliform.

INTRODUCTION

There were previous efforts or researches done on swine wastewater to reduce malodor and contaminants but no effective methods for their reduction have been achieved. In the biological treatment of wastewater, the most commonly used processes are (1) the activated-sludge process, (2) aerated lagoons, (3) trickling filters, (4) rotating biological contactors, and (5)stabilization ponds.

The activated-sludge process has been used extensively in its original form as well as in many modified forms.

The activated-sludge process have the following demerits :

(1) Although, it could be used to treat concentrated organic wastewater, such a system would be too expensive for pig breeding farms.
(2) it is difficult to select the type of reactor or reactors to be used in the treatment process.
(3) it includes construction,operation,and high maintenance costs, considered in conjunction with the secondary settling facilities.
(4) it is difficult to select the loading criteria by food-to-microorganism ratio(F/M), and the mean cell-residence time.
(5) the most common operational problem in the activated-sludges is the growth of filamentous microorganisms. A proliferation of filamentous organisms in the mixed liquor results in poor settling sludge.
(6) it is difficult to maintain dissolved-oxygen levels in the aeration tanks,to regulate the amount of return activated sludge, and to control the waste activated sludge.
(7) common problems are encountered in the operation of an activated-sludge plant, such as bulking sludge, rising sludge, and Nocardia foam. Few plants have escaped from these kind of problems.
(8) The various diffusion devices have been classified as either fine-bubble or coarse-bubble, with the connotation that fine bubbles were more efficient in transferring oxygen. The definition of terms and the demarcation between fine and coarse bubbles, however, have not been clear.
(9) it takes a long time for discharging from influx to efflux and decompose the swine wastewater, resulting in a biochemically stabilized product that is free from objectionable odour and that is a good source of organic nutrients.
(10) it is not economical for simple swine wastewater treatment systems.

The CRSS plants are characterized as an aerobic treatment process where by only swine wastewater is aerated intensively in the pipe into a bio-reactor. In the activated-sludge process, air application is generally not uniform throughout the tank length but partially intense in a pipe of the reactor. Activated-sludge solids are transported to the settle tank and separated naturally.

During the aeration period, adsorption, flocculation, and oxidation of organic matter occur continuously. The bubbles attach to the particulate matter, and the buoyant force of the combined particle and gas bubbles under the aerating pressure is great enough to cause the particle to rise to the surface. Particles that have a higher density than the liquid can thus be made to rise.

Finally, once the fine bubbles and particles have been floated to the surface, they can be transferred from the surface to the settle tanks through a tube.

The CRSS plants have the following general merits:

(1) the CRSS plants are useful for the economical treatment of concentrated organic wastewater.
(2) diversified selection of different types of reactors for the treatment process.
(3) the construction, operation, and maintenance costs, considered in conjunction with the secondary settling facilities are not necessary.
(4) the selection of the loading criteria by food-to-microorganisms ratio(F/M),and the mean cell-residence time is not necessary.
(5) the growth of filamentous microorganisms can be escaped.
(6) it is easy to maintain dissolved-oxygen levels in the aeration tanks, to regulate the amount of return activated sludge, and to control the activated sludge.
(7) No problems of the bulking sludge,the rising sludge,and the Nocardia foam.
(8) the fine bubbles of the various diffusion devices are useful for foams.
(9) it takes a short time for discharging from influx to efflux.
(10) it is economical and simple for swine wastewater treatment system.

The CRSS plants convert swine wastewater to transparent color and removes malodorants like ammonia and so on. During the continuous aeration for 9 days, the swine wastewater was changed to stabilized materials which are not hazardous. This paper describes the operational characteristics of promoting purification system of the CRSS plants and furthermore, it entails the usefulness of nutrient solution of effluent for the plant growth factories.

MATERIALS AND METHODS

Equipment And Operation Procedure

The chemical analysis was assayed according to the Japanese Industrial Standard (JIS) K-0102 (1996)

1. Experiment 1

This system mainly consists of a reactor tank(i.e.,only single stage), with an aeration pipe which have five-distributor holes for trickling of the upper level water, and a settling tank. 25 litres of wastewater for CRSS treatment were used and investigated. The CRSS plant had an overall dimensions of 300mm in diameter, and 350mm in depth, as shown in Fig. 1, schematic diagram of a single stage continuous removal of settling sludges (CRSS). The operating period was on June 25～July 4, 1996 (average temperature 23-25℃)

About 20 litres of swine wastewater was flushed into the tank through the inlet. These amount of 20 litres wastewater corresponds to that dropped out daily from pens with 3.5 swines. In aerobic conditions, air was passed upward through the unit from an air distributor located on top of the bottom pipe. Air was drawn continuously into the CRSS pipe of the plant through a mechanical blower fixed to the CRSS plants of the tank at the rate of 10 litres/min.

The microorganisms were not added at all to the tank during the experimental period. During aeration, the wastewater was foamed extremely in the pipe of the tank. Consequently, was transferred to the settling tank through a upper tube attached to the pipe by a buoyant force with aerated pressure and defoamed by an air pressure.

Experiment 2

The system was composed of four reactor tanks (i.e., single stage～four stage) and a settling tank for the solid matters, as shown in Fig.2, schematic diagram of a four stage continuous removal of settling sludges (CRSS).
Each tank was filled with 20 liters making a total of 80 litres solution of swine wastewater for purification. The total litres corresponds to that amount dropped out daily from pens with 14 swines. The operating period was from July 8-July 17,1996 (average temperature 24-26℃). The microorganisms were not added to the tanks during the experimental periods.

In aerobic digestion, CRSS method is equal to the modification of experiment 1. It is also applicable for treating any organic wastewater without addition of microorganisms into the reactor tanks.

In this system, contaminants in the bio-reactor tanks were removed continuously. The adsorption resulted continuously from fine bubbles into the pipe, flocculation and oxidization took place quickly and the period of decomposition of microoganisms was short.

RESULTS AND DISCUSSION

The CRSS plants have demonstrated considerable BOD removal and biological nitrification which was accomplished using aeration pipe by maintaining an aerobic environment. Table 1 shows the total results from individual analysis of the CRSS plants for experiment 1and 2, at the beginning and at the end of the treatment for 9 days.

There are five principal mechanisms by which the removal of residual or refractory organic material is accomplished in CRSS.

1. Soluble and colloidal organic wastes are converted to bacterial cells that may be separated from the wastewater.
2. The total mass of settleable and unsettleable cells is reduced through aeration pipe and concentrated in the settling tank.
3. Continuous removal of the suspended solids is possible to purify the wastewater in the reactor tank within a short period.
4. Organic material converted to biological growth and metabolism.
5. The synthesis, respiration,and adsorption is conducted rapidly in combination to remove organic material from swine wastewater.

Good BOD removal efficiency was obtained with final effluent BOD of 20mg/l, from influent 2,000mg/l to 20, about 99 percent of the BOD were removed in the CRSS plants through endogenous respiration by biological decomposition. No detrimental effects were observed in the CRSS plant.

Approximately 98.4 to 99.3percent of the SS were removed in the CRSS plants through effective bubble-making by intensive aeration in the pipe. Turbidity was reduced by about 98.5 to 99 percent,from 480 to 7 or 5 TU.

Total COD removed in the CRSS plants was about 70 to 71.8 percent , this was from 1,100 to 320mg/l. The most of COD in the effluent is inferred to the nonbiodegradable organics, original present influent, and by-products of biological degradation.

T-N in the CRSS plants was reduced from 1,300 mg/l to 100 or 60 a reduction of about (92.3 to 95.4)%. Ammonia nitrogen was reduced from 1300mg/l to 17 or 18 a reduction of about (98.6 to 98.7)%. The significant removal of ammonia nitrogen was observed for 9 days. The reason postulated was that the air flow rate was high enough to increase the DO to high level of nitrification. It is evident that nitrification in the CRSS system seemed to relate closely the intensive aeration rate such that NO_2-N,NO_3-N concentrations were very low as shown in Table 1.

The numbers of Coliform 4.5×10^3 in the influent were not detected in the final effluents. The CRSS plants are very effective for the reproduction of bacteria under the aerobic conditions. The microorganisms of this phase are forced to metabolize their own protoplasm without replacement because the concentration of available food is minimum.

TOC reductions during each operating period for 9 days are given in Fig. 3. Approximately 81.5 percent of the TOC were removed in the CRSS plants,with an average final effluent TOC of 224 to 243 mg/l. Most of TOC reductions occurred after 3 days of removal to an average of 73 percent for both exp 1and 2.

Therefore, the TOC reductions in the CRSS system showed close relationship to the aerating conditions for the reproduction and growth of microorganisms.

CONCLUSION

This system as an aerobic treatment process is characterized by which swine wastewater is only aerated intensively in the pipe into a bio-reactor. The CRSS systems are extremely interesting with respect to other solutions due to the technological simplicity to real operation.

The operation of CRSS is relatively simple compared with the operation of activated sludge systems. The CRSS systems have been shown to provide a high degree of polishing for effluents. Effluent BOD was reduced to below 20 mg/l (99 percent of samples), and SS concentrations were reduced to below 7 to 16 mg/l(about 98.9 percent of samples). Nitrification was accomplished throughout a operation period, and effluent ammonia nitrogen concentrations averaged less than 18 mg/l (about 98.6 percent of samples). Most of all, in the operation period CD(Coliform Number)was not detected from effluents in the CRSS plants. Effluent TU was reduced to below 5TU(about 99 percent of samples)

The qualities of final effluents in the CRSS plants for the swine wastewater treatment have been satisfactorily discharged criteria in to the river without the secondary treatment. The operational characteristics of this promoting purification system shows that the effluents can be reused as a nutrient solution or formulation for plant growth factories. The results shows that efflux obtained in Exp 1 and 2 had no significant difference in quality, However, the decomposition for Exp. 2 (multi-stage) was much faster than in Exp. 1(single stage). Multi-stage proved to be more useful for continuous treatment, but this needs to be researched further.

Although comprehensive design criteria have not been developed for CRSS systems, the studies and results reported in this paper do provide guidelines for the design of full-scale plants with a reasonable assurance of providing satisfactory livestock wastewater treatment.

The CRSS plant studies shall be continued in order to determine more detailed design criteria for CRSS systems for biological nitrification and for polishing effluents for additional BOD and SS removal.

REFERENCES

1. Salar NIku, E.D. and Schroeder, F.J. 1979. Performance of activated sludge processes and reliability-based design. Journal WPCF 51(12): 2841-2857.
2. Young et al. 1975. Packed-bed reactors for secondary effluent BOD and ammonia removal. Journal WPCF 47(1): 46-56.
3. Bruce et al. 1973. Further Studies of Partial Treatment of Sewage by High-

Rate Biological Filtration. The Institute of Water Pollution Control 499-523.
4. Richard, E.S. 1983. Anaerobic biotechnology for industrial wastewater treatment. Environ.Sci. Technol. 17(9): 416A-427A.
5. Thomas M.K. 1985. Operational dynamics and control of secondary clarifiers. Journal WPCF 57(7) : 770-776.
6. Barrett et al. 1960. Aeration studies at four weir systems. Water and Water Engineering : 407-413.
7. Nellor et al. 1985. Health Effects of Indrect Potable Water Reuse. Research and Technology : 88-97.
8. Orris E. A. 1987. The control of bulking sludges: from the early innovators to current practice. Journal WPCF, 59(4) : 172-182.
9. Ketchum et al. 1987. A comparison of biological and chemical phosphorus removals in continuous and sequencing batch reactors. Journal WPCF 59(1) : 13-18
10. Denny, S.P. 1983. Assessment of secondary clarification design concepts. Journal WPCF 55(4) : 349-359.
11. Burdick et al. 1982. Advanced biological treatment to achieve nutrient removal. Journal WPCF 54(7) :1078-1086.
12. Reed et al. 1986. A rational method for sludge dewatering via freezing. Journal WPCF 58(9) : 911-916.
13. Matasci et al. 1986. Full scale studies of the trickling filter / solids contact process. Journal WPCF 58(11) : 1043-1049.
14. Tchobanoglous et al. 1970. Filtration of treated sewage effluent. Journal of the sanitary engineering division : 243-265.
15. Charles R.O., 1967. Theory of Water Filtration. Journal of AWWA : 1393-1412.
16. Crittenden et al. 1978. Model for Design of Multicomponent Adsorption Systems. Journal of the environmental engineering division : 1175-1195.
17. Parker et al. 1987. Wastewater Technology Innovation for the Year 2000. National Conference on Environmental Engineering :487-506.
18. Task Committee on Belt Filter Presses. 1984. Belt Filter Press Dewatering of Wastewater Sludge. ASAE Task Committee : 991-1006.
19. Metcalf & Eddy. 1993. Wastewater engineering (Treatment, Disposal, and Reuse). Third Edition : 16-737.
20. Peavy et al. 1994. Environmental Engineering. Third Edition : 1-457.
21. Thomas, d. b., 1977. Biology of Microorganisms. First Edition : 1-189.
22. Shim, J.D., 1996. Study on the Systematic Technology of Promoting Purification for the Livestock Wastewater and Reuse. Master's thesis. : 1-148. Miyazaki University.
23. Dick et al. 1967. Evaluation of Activated sludge Thickening Theories. Journal of the Sanitary Engineering Division : 9-29.

Table 1. Physical and chemical properties of influx and efflux

	Units	Influx	Efflux(Exp.1)	Removal(%)	Efflux(Exp.2)	Removal(%)
Temperature	℃	22.5	20.5	—	19.2	—
pH	—	8.6	8.5	—	8.5	—
BOD	mg/l	2,000	20	99	20	99
COD	mg/l	1,100	310	71.8	330	70
TOC	mg/l	1,266	224	82	243	81
SS	mg/l	1,000	7	99.3	16	98.4
T-N	mg/l	1,300	100	92.3	60	95.4
NH_4-N	mg/l	1,300	18	98.6	17	98.7
Org-N	mg/l	72	33	54.2	35	51.4
NO_2-N	mg/l	0.02	31	—	3.3	—
NO_3-N	mg/l	0.4	2.8	—	0.5	—
NH_3	ppm	400	ND	100	ND	100
T-P	mg/l	110	110	0	49	55.5
Coliform	n/ml	4,500	ND	100	ND	100
TU	TU	480	7	98.5	5	99
Color	—	yellow	brown	—	brown	—

* N.D.: Not detected

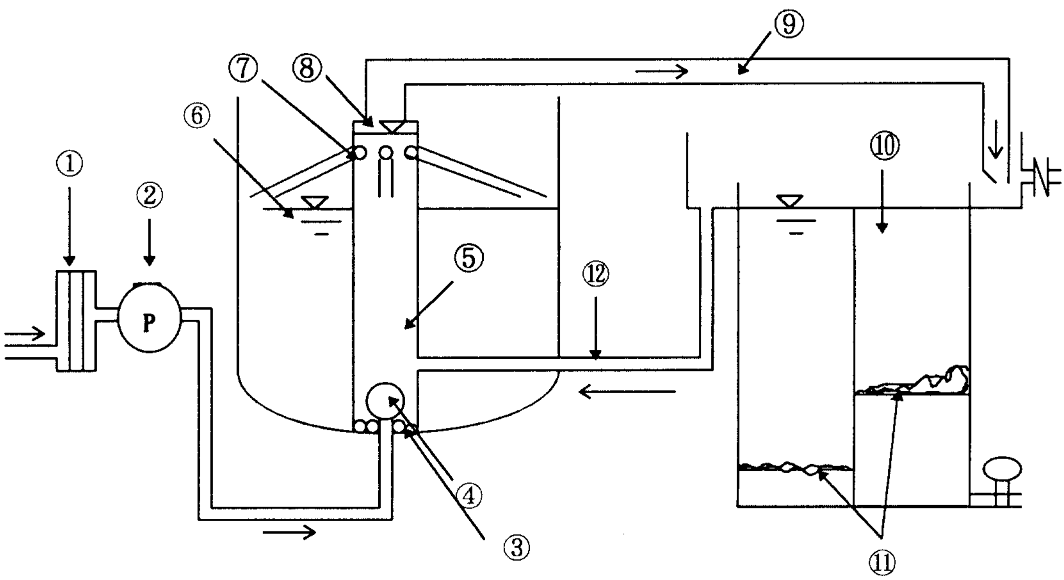

Fig. 1. Schematic diagram of a single stage continuous removal of settling sludges (CRSS)

1	air flow metre	2	blower(pump)
3	wastewater inlet hole	4	diffuser
5	intensive aeration pipe	6	water level
7	distributor for trickling	8	upper water level
9	bubble transfer tube	10	settling sludge
11	sludge thickening	12	return the upper wastewater

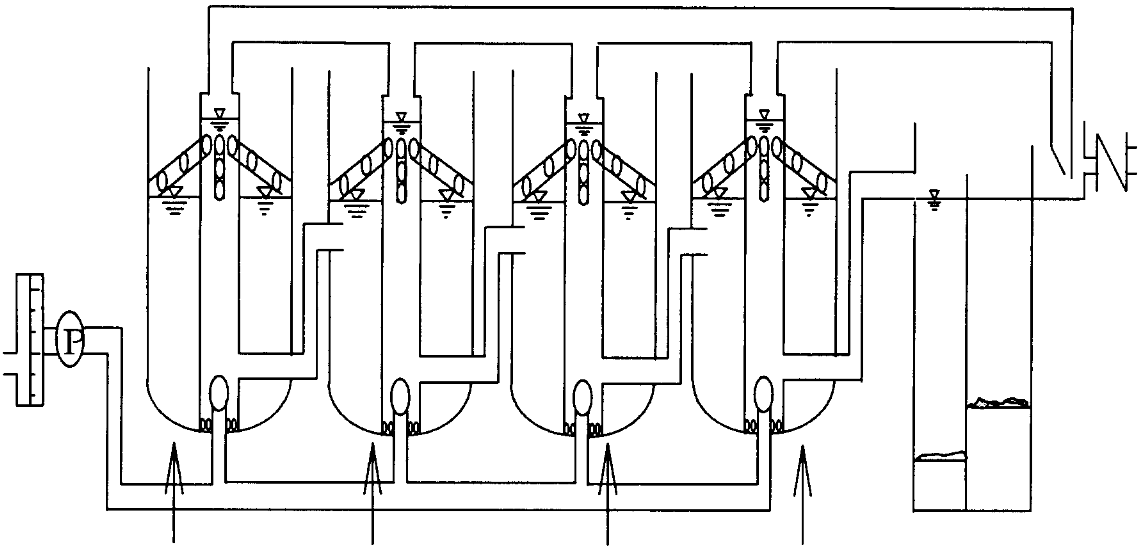

Fig. 2. Schematic diagram of a four stage continuous removal of settling sludges (CRSS)

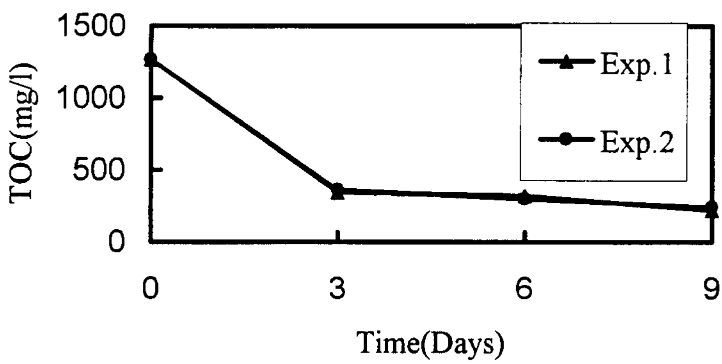

Fig.3. Influx and Efflux on TOC