Recycling Studies for Swine Manure Slurry Using Multi Process of Aerobic Digestion (MPAD)

Kim, Soo Ryang[1], Yoon, Seong Ho[1], Lee, Jun Hee[2], Lee, Myung Gyu[1]

[1]Dept. of Environmental Engineering, Sangji University, Korea
[2]Dept. of Architecture and Urban Science, Chiba University, Japan
E-mail: mglee@sangji.ac.kr

This study was carried out to investigate the feasibility of Multi Process of Aerobic Digestion(MPAD) for recycling of swine manure slurry as fertilizer. MPAD consisted of three kinds of difference process which are thermophilic aerobic oxidation (TAO) system, lime solidification system, and reverse osmosis(R/O) membrane system. TAO system was studied well previously for decade. The chemical composition of the lime-treated solid fertilizer was as like that organic matter 17.4%, moisture 34.1%, N 0.9%, P 1.7%, K 0.3%, Ca 12.7%, and which was expected to be useful as acid soil amendment material. The concentrated liquid material produced by R/O membrane system was also expected as a good fertilizer for crops production and soil fertility improvement.

Keywords: MPAD, TAO system, lime Solidification, R/O Membrane, liquid fertilizer

Introduction

Livestock farming had been used as a part time job for labors and had been made in the form of moonlighting in agriculture. Furthermore, livestock wastes were used to fertilize in agriculture lands. However, the amount of people spends on milk and meats has increased because of the livestock promotion policy of the government and the increase of people's income. As a result, they caused an increase in livestock numbers after 1990. The farming became a big business and a full time job. Because of increasing the livestock numbers, the pollution from animal excrements was destroying environment. Especially, pig wastes are the most related factor for that.

The government has a restricted policy for operating livestock night soil treatment facilities but not for composting and liquefying that can be recycled. Animal waste could be used as a chemical fertilizer alternatively. Yet, most of the farm households try not to use it for the reason that they doubt its effect.

On the other hand, lime has been added into farmlands for 30years, the most of them are still acidic. The general method to reduce the acidity is increasing pH in the acid soils by using lime substance. Soil neutralization is helpful in order to promote plant growth, fertility, and nutrient efficiency. Recently, developments in technology make more fertilizing methods by mixing with lime in animal composts and liquefied manure.

In this experiment, biological, chemical, and physical processes were made separately to recycle livestock excrements efficiently. Multitask process aerobic digestion was developed to recycle livestock wastes in each process and was applied in a field. A product from each process was analyzed for possibilities of fertilizer utilization.

Materials and Methods

1. Materials

The livestock waste used for this experiment was obtained from a pig farm in Wonju city, Kangwondo. The average bio-chemical characteristics of the swine manure slurry was pH 7.1, Total solid(TS) 5.1%, BOD_5 534,540mg/L, COD_{Mn} 25,877mg/L, SS 40,927mg/L, T-N 4,864mg/L, and the bacteria 47,837 CFU/㎖ (Table1).

Table 1. The Bio-chemical characteristics of swine manure slurry.

Item	Conc.
pH	7.1
TS (%)	5.1
BOD_5 (㎎/L)	34,540
COD_{Mn} (㎎/L)	25,877
SS (㎎/L)	40,927
T-N (㎎/L)	4,864
T-P (㎎/L)	1,082
E. coli (CFU/㎖)	47,837

2. Experimental Equipment

1) Thermophilic Aerobic Oxidation System

Crude particles in livestock wastes and Grift were removed in a screw creen. For the steady rate of fluctuation or equipment repair, a storage tank was prepared so that the amount of the livestock wastes and water quality could be consistent. By doing that, the process could be done efficiently and the water quality could be good. The wastes in a manure tank were transferred to the biological process, the thermophilic aerobic oxidation system by using a pump. Strong mixing and aeration were performed at the same time so self heat (autothermophilic) reaction was induced due to thermophilic bacteria.[3.4.5)]

2) Lime solidification system

It is a devise to make lime solidified particles. Floating particles in the livestock wastes could be solidified. It is composed of a condensed sample control part, 1st condensation part, 2nd condensation part and a filter press. In the control part, to process thermophilic aerobic fermentation liquor, lime was added to increase pH up to 9~12. Into the liquid, the solidification of the liquid was maximized after adding Iron chloride, polymer coagulant. Then, it was filtered by the filter press.[2)]

3) Reverse Osmosis System

Reverse Osmosis is a selective penetration membrane system to remove dissolved solids like metal ion. It is composed of a pre-pump and a high pressure pump for osmotic pressure.[6)]

3. Analysis

In the case that sludge was analyzed by including incoming and out flowing water, the categories of the analysis was usually pH, organic substance (COD_{Mn}, BOD_5), nitrogen(T-N), phosphorus(T-P), solids(SS,TS), E-coli bacteria and etc. A sample in each process was obtained and analyzed. The water quality analysis categories were followed by standard method for examination of water. Solids were analyzed in fertilizer standards shown as N, P, K, Ca, S, Pb, Cd, Cu, Cr, As, Hg, Ni, Zn.

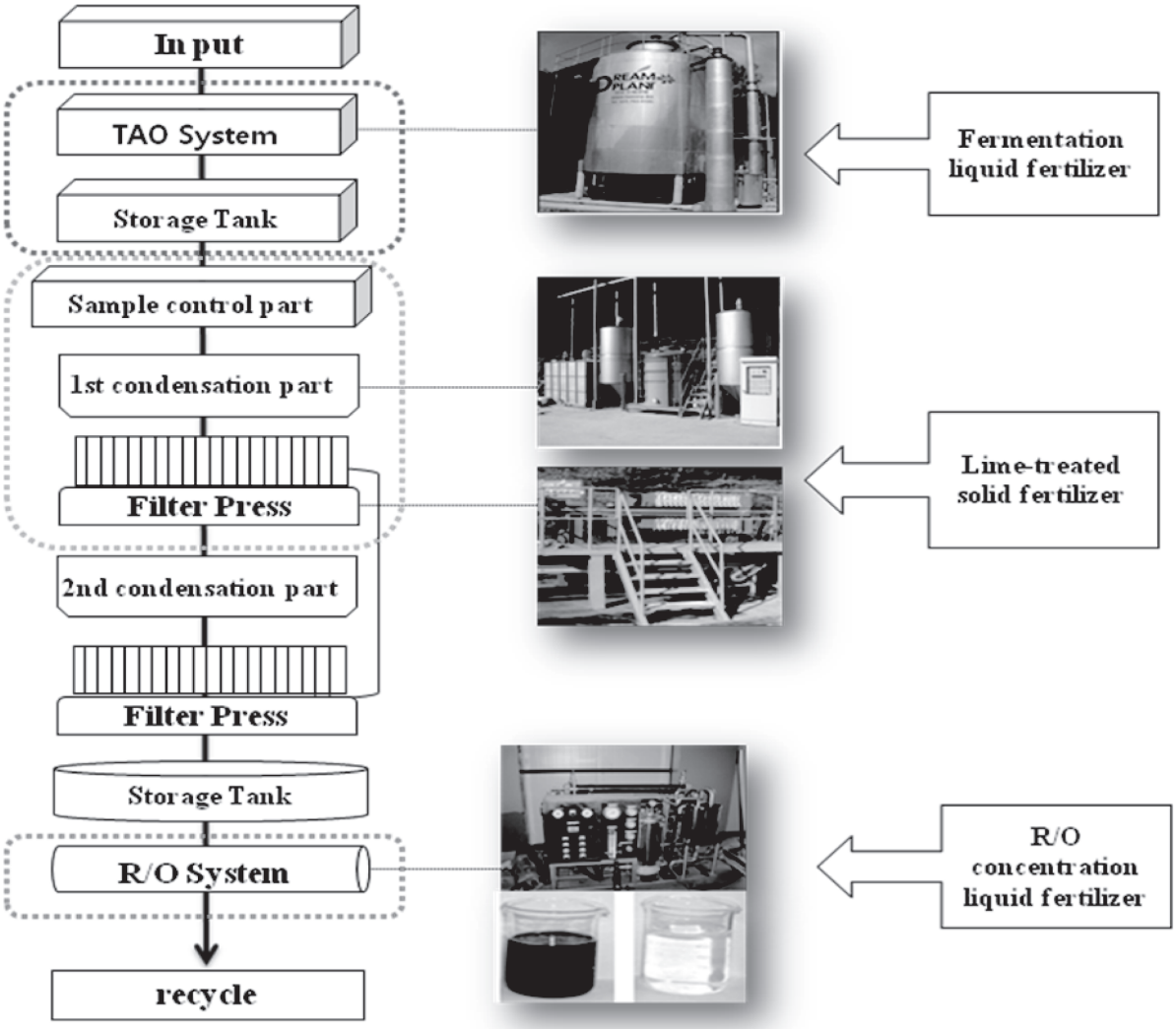

Fig 1. Scheme of the MPAD system

Results and Discussion

1. Concentration changes for each process and processing efficiency

The average BOD_5 concentration of incoming water was 34,540mg/L. The BOD_5 concentration of out flowing water was 15mg/L. So, it showed 99.9% efficiency. The COD_{Mn} concentration of the incoming water was 25,877mg/L. And, the concentration COD_{Mn} of the out flowing water was 25mg/L. So, it showed 99.9% efficiency. The result showed that the most of the organic substance were removed. The SS concentration of the incoming water was 40,927mg/L. The SS concentration of the out flowing water was 3mg/L. It showed 99.9% efficiency. The T-N concentration of the incoming water was 4,864mg/L. The T-N concentration of the out flowing was 1,082mg/L. By showing 99.1% efficiency, most of the nitrogen was removed. The T-P concentration of incoming water was 1,082 mg/L. The concentration of out flowing water was 9mg/L. By showing 99.9% efficiency, most of phosphorus was removed. concentration changes for each process and processing efficiency were demonstrated in Table 2.

2. The fermented liquid by Thermophilic Aerobic Oxidation devise

Due to autothermophilic reaction, pathogenic microorganisms were inactivated by high temperature in the biological process, Thermophilic aerobic oxidation system. Because of thermophilic bacteria and removing organic substances, ammonia was formed. And, there was an increase in pH. Rising pH in high temperature evaporates ammonia and removes nitrogen.[1,7] The processed fermentation liquor was shown in Table 3.

3. Solids precipitation by Lime solidification system

The Table 3 shows analysis of solid precipitations in 1st condensation and 2nd condensation parts. The result shows that each heavy metal concentration was Pb 21.6 ㎎/㎏, Cd 0.9 ㎎/㎏, Cu 227.6 ㎎/㎏, Cr 17 ㎎/㎏, As no detection, Hg no detection, Ni 12.1 ㎎/㎏, Zn 541.5 ㎎/㎏. Cupper and Zinc was slightly high. It shows that the solids became useful fertilizers by including 17.4% of organic substances and N 0.8%, P 1.7%, K 0.3%. Also, they contained 34.1% water. The water regulators would not be necessary.

Table 2. Bio-chemical concentration in each step of MPAD system.

Item	BOD_5 (mg/L)	COD_{Mn} (mg/L)	SS (mg/L)	T-N (mg/L)	T-P (mg/L)	E. coli (CFU/㎖)
Influent	34,540	25,877	40,927	4,864	1,082	47,837
Fermentation liquid fertilizer	8,286	10,036	38,117	3,846	964	N.D*
1st Lime solidification	3,729	5,019	1,042	3,113	29	-
2nd Lime solidification	1,119	2,510	150	2,959	7	-
R/O concentration liquid fertilizer	4,121	5,268	255	5,261	16	-
Discharged water	15	25	3	43	0	-
Efficiency(%)	99.9	99.9	99.9	99.1	99.9	100

*N.D : Not Detected

Table 3. Physico-chemical characteristics of Lime-treated solid fertilizer.

Item	Lime-treated solid fertilizer	Item	Lime-treated solid fertilizer
pH	9.6	**Pb (mg/kg)**	21.6
Organic matter (%)	17.4	**Cd (mg/kg)**	0.9
Moisture (%)	34.1	**Cu (mg/kg)**	227.6
N (%)	0.8	**Cr (mg/kg)**	17
P (%)	1.7	**As (mg/kg)**	N.D
K (%)	0.3	**Hg (mg/kg)**	N.D
Ca (%)	12.7	**Ni (mg/kg)**	12.1
S (%)	0.3	**Zn (mg/kg)**	541.5

Table 4. Heavy Metal concentration in each liquid fertilizer MPAD system.

Item (mg/kg)	Fermentation liquid fertilizer	R/O concentration liquid fertilizer
Pb	0.2	N.D
Cd	0.03	N.D
Cu	41.4	9.9
Cr	0.3	0.1
As	0.1	0.014
Hg	N.D	N.D
Ni	N.D	N.D
Zn	95.9	2.4

4. The heavy metal concentration by Reverse Osmosis system

The major heavy metal concentration of the R/O concentrated liquid from the last process, R/O system were shown in Table 4. Reverse Osmosis is a separate penetration to remove dissolved solids like metal ion. The equipment is composed of a pre-pump and a high pressured pump for osmotic pressure. The pressured pump separates condensed liquid and out flowing water.

5. The analysis of the concentration of out flowing water in R/O

Fermentation liquid, solids, and condensed liquid were produced through the whole process such as thermophilic aerobic oxidation devise, lime solidification devise and reverse osmosis devise. The out flowing water occurred by the end of the process. The water was analyzed by the standard wastewater discharge standards. The standards

says that BOD_5, COD_{Mn}, SS, T-N, T-P, bacteria should be measured, the average concentrations of the out flowing water were BOD_5 15 ㎎/L, COD_{Mn} 25 ㎎/L, SS 3 ㎎/L, T-N 43 ㎎/L, T-P 0 ㎎/L, and no bacteria found. Therefore, they are lower than the standard concentrations which are BOD_5 30 ㎎/L, COD_{Mn} 50 ㎎/L, SS 30 ㎎/L, T-N 60 ㎎/L, T-P 8 ㎎/L. The water is suitable for the standards. It seems that the water can be used as sewage or recycled water.

Conclusion

Livestock wastes were transformed into the processed fermentation liquid, organic lime fertilizer, and R/O condensed liquid by using the biological process, "thermophilic aerobic oxidation system", the chemical condensed process, "lime solidification system" and, the physical process related to R/O system, "multi process aerobic digestion system." The results were explained below.

1. The concentrations of the fermentation liquid in the thermophilic aerobic oxidation system were BOD_5 8,286mg/L, COD_{Mn} 10,036 ㎎/L, SS 38,117 ㎎/L, T-N 3,846 ㎎/L, T-P 964 ㎎/L, and no bacteria found.
2. The precipitations of the solids in lime solidification system were organic substance 17.4%, water 34.1%, Ca 12.7%, Pb 21.6 ㎎/㎏, Cd 0.9 ㎎/㎏, Cu 227.6 ㎎/㎏, Cr 17 ㎎/㎏, As no found, Hg no found, Ni 12.1 ㎎/㎏, and Zn 541.5 ㎎/㎏. The amounts of copper and zinc were little higher than the average. But, they are still lower than the fertilizer standards which are 300mg/kg and 900mg/kg. The concentrations of the other heavy metals are also lower than the standards. They also have enough of organic substances, nitrogen, phosphorus, and potassium. It shows that the solids become useful fertilizers. Further, 34.1% water dries naturally. Thus, the water regulators would not be necessary.[3)]
3. The concentrations of R/O concentrated liquid in the reverse osmosis system were BOD_5 4,121 ㎎/L, COD_{Mn} 5,268 ㎎/L, SS 255 ㎎/L, T-N 5,261 ㎎/L, T-P 16 ㎎/L and no bacteria found. R/O concentrated liquid is expected to be used as customized liquid under rural environments and living conditions of field farm products.
4. The average concentrations of the out flowing water from the reverse osmosis system were BOD_5 15 ㎎/L, COD_{Mn} 25 ㎎/L, SS 3 ㎎/L, T-N 43 ㎎/L, T-P 0 ㎎/L, and no bacteria found. They are all lower than the standards which are BOD_5 30 ㎎/L, COD_{Mn} 50 ㎎/L, SS 30 ㎎/L, T-N 60 ㎎/L, T-P 8 ㎎/L. The water is suitable for the standards. It seems that the water can be used as sewage or recycled water.

Application

In this experiment, the livestock wastes were used by applying biological, chemical, physical processes. To recycle the wastes in each process, multitask process aerobic digestion was developed and applied in a field. Fertilization availabilities of products by each process were reviewed. Especially, solids by lime solidification devise have a possibility to be used as a recycling soil conditioner.

Most Korea soils are acid except for areas such as, kangwondo youngwol, jungsun, chongchungbukdo danyang, kyungsanbokdo munkyung and etc. Also, mining active areas become more acidic and were contaminated as a result of minerals and mining wastes. When acid waste water or leachate are disposed, a neutralization method is used generally. For the neutralization, lime substances which have high alkalinity are used. For forest restoration and improvement of soils, lime substances also are applied into cover materials or fertilizers to restore the contaminated soil.[8)]

Lime solidified solids have more lime materials and organic substances than general compost. Further, different sized pellets can be produced.[2)] Therefore, the products can be used for not only high quality of composts, but also for soil conditioners.

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