B-16.9.2 Development of Appropriate Wastewater and Sludge Treatment Technology for Controlling CH_4 and N_2O Emission Applicable to Korea (Final Report)

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Abstract To deal with the rapid deterioration of the water environment that has occurred in recent years at dam reservoirs and other water resource areas located close to farming and rural communities in Korea, methods of treating domestic wastewater and live-stock wastewater are being improved. The number of small scale treatment plants processing domestic and live-stock wastewater in these regions is, therefore, forecast to increase. This means that to deal with the sludge that will be produced as a by-product of this wastewater treatment, there is an urgent need to develop small scale treatment methods rather than the large scale treatment methods provided in the past. This research study, one undertaken in light of the above circumstances, was a study of the application of the thermophilic oxic process method, one that is based on the familiar principle of the composting reaction and permits the total decomposition of organic material, to the treatment of sludge and high concentration organic wastewater produced by live-stock raising. The results have shown that because these organic materials have high water content, a heat source such as waste food oil must be added to them, and that according to the quantity added, there may be insufficient nitrogen for the reaction. It is, therefore, important to provide the optimum water content and C/N ratio.

Key Words : Thermophilic Oxalic Process, Greenhouse gas, Live stock wastewater, Jokasou sludge, Korea

1. Introduction

Rapid progress in the improvement of methods for use in small scale domestic wastewater treatment facilities and live-stock wastewater treatment facilities has been achieved in recent years in Korea in an attempt to preserve the water environments in water resource regions. Under these social conditions, it is forecast that in Korea as in Japan, environmental preservation will eventually be an important issue in agricultural and rural communities, but no effective processes have been established for the effective treatment and disposal of sludge produced by the treatment of domestic wastewater, nor of the crop residue and highly concentrated fluid organic waste matter such as live-stock feces etc. that are waste materials produced by agricultural and livestock breeding, which are both important industries in agricultural and rural regions. This research study, one undertaken in light of the above circumstances, was conducted in order to obtain basic knowledge needed to establish treatment, disposal, and recycling systems for organic waste material in the agricultural and rural communities of Korea. To achieve this goal, it focused on thermophilic oxic process as an advanced method of treating and disposing of live-stock waste fluids and other waste material produced in agricultural and rural communities in order to clarify the treatment properties of waste fluid from live-stock barns and sludge from jokasou used as small scale or on site domestic wastewater treatment systems.

2. Experimental Method

The thermophilic oxic process is based on the principle that organic material is aerobically decomposed at a high temperature of about 60 ℃, a process basically identical to composting. The two processes differ in that while composting is performed primarily on solid organic material with low water content, the thermophilic oxic process method is used to process liquid high concentration organic waste fluids. The sawdust etc. that is placed inside the reaction chamber is not added as a component for composting; its role is that of a carrier that maintains ventilation to encourage the decomposition of the organic material, adjusts the water content, and provides a habitat for microorganisms. It is repeatedly agitated during the injection of waste fluid in order to mix and homogenize the inside of the chamber to encourage decomposition, and it forcefully provides continuous ventilation from the bottom of the reaction chamber.

The mini-plant was used for this experiment . A cylinder with an internal diameter of 200 mm and a height of 220 mm, its effective capacity is 4 L, and it is equipped with a fan shaped agitator to mix the materials inside the chamber. To prevent heat loss, the entire reaction chamber is insulated with a layer of Styrofoam 40 mm in thickness. Its sludge decomposition capacity is monitored by placing the apparatus directly a scale. The carriers used were two sizes of scrap wooden chips (ones with a diameter from 1 to 1.5 mm, and other between 5 and 10 mm on all sides and 0.2 mm thick). The sample fluids included some taken from a pig sty where it is difficult to separate the feces and urine and sludge from a jokasou.

The mini-plant was placed inside a room with a constant temperature of 30 ℃, and when the process started, 3 L of the carrier material were placed inside the reaction chamber and 100 grams of swine feces or sewerage sludge compost was added as the seed, then the waste fluid was mixed with it until the moisture content reached 50% and specimen waste fluid was injected into each system once every day. The mixture of the carrier and the waste fluid inside the chamber (referred to as the "mixture" below) was agitated for about 30 minutes after the waste fluid was injected.

3. Results and Discussion

3.1 Swine Waste Fluid Treatment

It was revealed that the conditions permitting brisk organic material decomposition using this method are a BOD load of 3.0 $Kg \cdot m^{-3} \cdot day^{-1}$ and ventilation quantity of 100 $L \cdot m^{-3} \cdot min^{-1}$ at which the fermentation temperature reached approximately 60 ℃. The results of a calculation of the organic carbon balance per cycle based on the CO_2 gas concentration produced after sample injection reveal that 80% of the organic material was decomposed by CO_2, but this reaction stopped after the first five days, sharply lowering the temperature inside the reaction chamber, and although it was not confirmed that there was drain water at the bottom of the reaction chamber, the water content of the mixture gradually increased from the initial 50% level. Based on this, it was concluded that a supplementary heat source was needed to encourage the decomposition of the swine waste fluid and the evaporation of the water. So an attempt was made to maintain the quantity of heat by mixing used waste cooking oil with a BOD higher than 2 million $mg \cdot L^{-1}$ with the swine waste fluid. So waste cooking oil equal to about 10% by weight of the waste swine fluid with a BOD load of 3.0 Kg・m^{-3}・day^{-1} was added to the swine waste fluid once a day, and it was ventilated at a rate of 100 L・m^{-3}・min^{-1}. Four days after the experiment started, the maximum temperature of the mixture reached approximately 70 ℃, and afterwards, the maximum temperature remained constantly between 60 ℃ and 70 ℃ about three hours after waste fluid was injected, the water content after decomposition was completed was stable between 30% and 50%, and no drain water was discharged. The weight of the mixture did not increase. These findings indicate that in its stationary state after four days, the organic material in the injected waste fluid including the used cooling oil was almost completely decomposed, that the heat this produced completely evaporated the water content, and that almost no excess sludge was produced.

An examination of changes in the number of thermophilic bacteria performed throughout the process reveals that it increased rapidly from its initial 10^8 N per gram of dry carrier by weight to 4 X 10^{10} N after 5 days, and that after the fifth day when the process began to proceed stably, it was at a stable level between 10^{10} to 10^{11} N or about 100,000 times the initial level of 10,000.

These findings show that based on this method, it is possible to stably and efficiently decompose organic material and evaporate its water content by controlling conditions such as heat quantity and water content, etc. at appropriate values and by maintaining the thermophilic bacteria at between 10^{10} and 10^{11} N per gram of dry carrier by weight.

3.2 Jokasou sludge Treatment

The characteristics of treatment of jokasou sludge were studied by setting the load conditions, the quantity of cooking oil added as a supplementary heat source, and the quantity of ventilation provided to the apparatus that were considered optimum in light of the results of the swine waste fluid treatment experiment. But because jokasou sludge contains less nitrogen than swine waste fluid, there was a possibility that the fermentation would be limited by an increase in the C/N ratio in the overall system caused by the addition of cooking oil containing no nitrogen. In a normal composting process, the decomposition of the organic material advances quickly in a range from 10 to 30, so to study the effects of the C/N ratio, the C/N ratio was set at 12 and at 24 by adding appropriate quantities of urea.

The jokasou sludge experiment indicated treatment characteristics almost identical to those observed in the swine waste fluid case at a C/N ratio of 12, but when the C/N ratio was 24, fermentation occurred slowly, the fermentation temperature was only 50 ℃, which was lower than the 70 ℃ obtained at a C/N ratio of 12, and the organic material decomposition rate was only about 50% of the material supplied. And the concentration of the ammonia generated in the C/N ratio of 12 case, was high at an average value of 300 ppmv, indicating that sufficient nitrogen had been provided for fermentation. In contrast, in the C/N ratio of 24 case, no ammonia was detected in the exhaust, suggesting that overall the system is short of nitrogen. But this result indicates that by appropriately combining waste materials with different C/N ratios, it is possible to adjust the C/N ratio, eliminating ammonia from the foul smelling exhaust. Further studies must be conducted to determine the appropriate combinations of waste materials.

4. Summary

Waste materials produced by domestic activities include sewage sludge, jokasou sludge, food waste, highly concentrated organic waste fluid generated by food processing etc., rice hulls, crop residue, wood scraps, destruction rubbish, and sawdust. While sewage sludge, jokasou sludge, food waste, livestock barn waste, etc. are generated continuously throughout the year, the quantity of other forms of waste material fluctuates sharply from place to place and season to season. For example, crop residue, rice hulls, and other materials generated by agricultural activities are only generated during the harvest season. And in some food processing industries, the amount of organic waste material generated is governed by the season the crops are harvested and the quantities harvested. In this case, lage quantities of the waste material are generated during limited times of year.

To treat and dispose of these waste materials independently in each district would be time consuming and the provision of separate facilities for each district would be extremely expensive. Therefore, because of the slow development of incineration facilities in particular, in Korea, almost all organic waste material is disposed of by using it as landfill or dumping it offshore. For this reason, it is essential that, wherever possible, organic waste material treatment, disposal, and recycling systems be established as regional systems in order to prevent the contamination of the country's closed water regions or its underground water.

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