폐기물자원화
제 7 권 제 2 호, 57~64 1999

고온호기발효장치를 이용한 조류 분해 및 가스 발생특성

강 창민

초당대학교 환경공학과

The properties of algal degradation and gas emission by thermophilic oxic process.

Changmin Kang

Dept. of Environmental Engineering, Chodang University

ABSTRACT

The purpose of this study is to establish effective conditions for controlling CH_4, N_2O emission from organic waste/wastewater treatment processes. Continuous and batch experiments were conducted to treat the micro algae from polluted and eutrophicated lakes through the thermophilic oxic process. The microalgae used were mainly Microcystis sp. (collected from eutrophic lake) and Chlorella sp.. (cultured in laboratory)

Wasted cooking oil was added by aid-heating source. Physico-chemical components of sludges and microalgae were analyzed. In batch experiments, air supply was changed from 50 ml/min to 150ml/min. The temperature, water content and drained water were affected by the air flow rate at initial stage. However, there was almost no influence of air flow rate on them in middle and last stages. At air flow rate of 100ml/min, the degradation rate of organic material was higher than that at other air flow rates. CO_2 concentration in exhaust was proportional to the strength of aeration, especially at initial stage when degradation was active. CH_4 with low concentration was detected only at starting stage when air diffusion was not enough. N_2O production was not affected by variation of air supply.

In continuous experiments no matter what the dewatering methods (with PAC and without PAC) and media (wood chip and reed chip) were changed, N_2O was almost not affected by variation of injected air. Result showed that the reed chips using for lake purification could be used as media for thermophilic oxic process in lake and marshes area. CO_2 concentration was not so much affected by the change of dewatering methods and media types. CH_4 was not detected in the experimental period. So it can be shown that the thermophilic oxic process had been well operated in wide handling conditions regardless of media and dewatering methods.

Key Words : global climate warming, thermophilic oxic process, CO_2, N_2O, CH_4

초 록

본 연구는 고온호기발효법에 의해 미세조류(부영양화호에서 회수한)를 처리할 경우, 처리조건의 변화에 따른 지구온난화가스의 발생특성을 살펴, 가스억제를 위한 효과적 처리조건을 검토하는 것이다. 회분 및 연속실험을 실시하여, 이하의 결과가 얻어졌다.

회분실험에서는 폐식용유의 첨가유무 및 공기주입량에 따른 발효효과를 검토했다. 폐식용유 첨가의 경우, 발열량의 증가에 따라 처리물질의 수분증발에 효과적 이었다. 또 공기주입량의 변화에 따라, 유기물제거는 공기량이 100ml/min일 때 가장 효과적이었고, 발생가스중 CO_2는 실험초기에만 영향을 받았고, N_2O는 실험중 전혀 영향을 받지 않았다. 또 CH_4는 공기공급이 부족한 초기에 검지 되었으나, 그 후 발생되지 않았다. 연속실험에서 공기량을 100ml/min에 고정한 후,고분자응집제의 첨가유무 및 수분조정제의 종류에 따른 가스발생특성을 비교 검토했다. N_2O는 고분자응집제(PAC) 첨가 및 수분조정제의 종류에 의해 가스발생량에 영향을 받지 않았으나, CO_2의 경우는 약간의 영향을 받았다. CH_4는 검출되지 않았다.

주제어 : 고온호기공정, 미세조류, 공기량, CO_2, N_2O, CH_4

1. Introduction

Nowadays, global climate warming caused by green house gases (for example, CO_2, N_2O, CH_4) is noticed in worldwide. Rapid economic growth and industrialization have led to some serious environmental problems, such as emission increase of greenhouse gases. The sources of emitted gas are mainly distributed in stack of plant[1], waste/wastewater treatment process, rice field[2] and lake. Concentrations of N_2O, CH_4 in atmosphere are very low, however green house effect on N_2O is 200-300 times high of that of CO_2 and CH_4 is 20-30 times high of that of CO_2[3].

CO_2, N_2O and CH4 from organic waste/wastewater treatment process was growing year by year. Rate of CO_2, N_2O, CH_4 from organic waste treatment facilities to all human-related CO_2, N_2O, CH_4 emission are 3.6%, 21%, 37%, respectively[4]. So, it is necessary to develop some new effective treatment processes to reduce greenhouse gas emission now. On the other hand, composting which is in most respects similar to thermophilic oxic process has been used in rural area for many years. And it has been reported that the composting is one of the low gas-emitted treatments[5]. The purposes of this study are not only to determine the optimum operational conditions for the complete treatment of organic waste but also to minimize N_2O, CH_4 emission from its operation. In addition, the fetilization as a link of energy recycle is also examined.

2. Materials and Methods

2.1 Experimental apparatus

The schematic diagram of the experimental reactor used in this study is shown in Fig. 1. The reactor (volumne 5L, ø 200 mm, 220 mm high) consisted of cylindrical polyacryl chloride bottle with a perforated plate at the bottom to distribute the air which was supplied from an air pump. The reactor was enveloped by cubic styrofoam (thickness: 40 mm) insulation to keep minimum heat loss from the reactor. The diameter of a hole was 1.5 mm in order to prevent the cedar chips from passing through it.

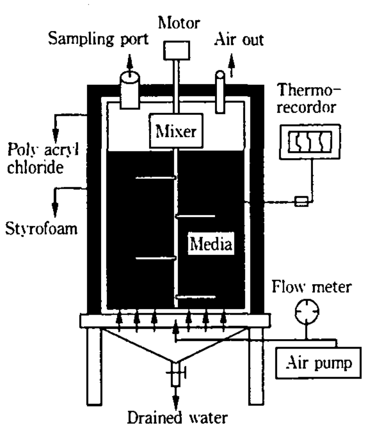

Fig. 1 Schematic diagram of experimental apparatus.

2.2 Operating conditions

The 3L of cedar chips were put into the reactor to keep aerobic condition and controlling moisture content. The size, diameter of pores, specific surface area and water holding capacity of cedar chip were 2-7 mm, 40-50μm, $2.5m^2$ and $2.53g \cdot g^{-1}$ respectively, which meant cedar chip are also a good habitats for microorganisms to attach[6]. Quantities of microalgae, compost and wasted food oil were determined according to experimental conditions. The mixing ratio of amount of cedar chips to algal liquid to compost was 30: 1: 1. In this mixture, compost was used as an inoculum. Microalgae, compost and wasted cooking oil were put into the media and completely mixed. Then mixtures were put into the reactor.

Wasted cooking oil was added to provide energy source for the evaporation of moisture. The agitation of medium for the prevention of occurrence of an anaerobic state was conducted by hand at least once a day. The reactor was placed on a balance in order to continuously measure the weight. Air was supplied by an air pump and its flow rate was determined by air flow meter. The temperature was measured by using thermometer inserted into the medium at the center of reactor. At the beginning of the batch experiments, cedar moisture and air flow rate were 70% and 100 ml/min, respectively. Later they changed as followings : cedar moisture 55%[6] and air flow rate 50, 100, 150 ml/min, respectively[7]. The substrate was Chlorella sp. cultured in commercial scale plant.

In the continuous experiments, air flow rate was fixed to 100 ml/min. The substrate with/without PAC(Poly Aluminium Chloride) and media kinds(cedar chip and reed-chip) were changed. The substrate was Microcystis sp. (ordinarily called by Aoko) collected from Lake Kasumikaura in Japan.

2.3 analytical methods

Total solid, volatile solid and moisture content were determined as described by Sewage Analysis methods[8]. CO_2 concentration was measured by detecting tube (GasTeck, model No. 2H (1%~10%), 2L(0.25-3%). CH_4 and N_2O concentrations were measured by Gas Chromatography (FID, TCD) (Shimadzu corp.). The calorie(kcal/kg) of microalge solid was calculated by Dulong equation.

2.4 Composition of material

The physico-chemical characteristics of microalgae and sludge from agriculture and livestock farm and primary sludge are shown in Table 1. There was little difference in C content among the wastes. And N content of microalgae is higher than that of others. Contrary to the N content, P content of microalgae is less than that of others. And pig and cattle showed higher C/N ratio than others. The addtion of carriers is needed to keep the reactor aerobic because water content of all the used-wastes is high. Total solids(TS) of all wastes were 20~30% except microalgae and cattle. The content of protein, lipid, carbohydrate, ash, and chlorophyll in microalgae were 67.48%, 13.85%, 8.94%, 6.81%, and 2.90%, respectively. It is commonly thought that the maximum permissible density for composting is below 900 kg/m^3. Since the density of microalgae (kg/m^3) was 1010~1030, a proper density control was needed to effectively treat it[9]. Mean caloric value (kcal/kg) of dried micro algae was 5451.8 if calculated from mean calories of protein, lipid and carbohydrate[9], but it was 5201.3 if calculated by Dulong equation (C, H, O and N). Mean caloric values (kcal/kg) of compost, kitchen waste and cattle nightsoil were 4400, 4598 and 4950, respectively.

Table.1 Phyco-chemical chracteristics of organic matcrial

Item	C	N	P	C/N	Moisture	Total solid
Microalgae	51.49	9.47	1.95	5.4	87	12.9
Domestic fowl	42.2	4.6	4.52	9.0	75~80	20~25
Pig	41.5	3.9	4.8	11.0	81.1	18.9
Cattle	41.4	1.8	2.7	23	84.3	16.7
Activated sludge	-	6.0~5.6	3.2~5.7	-	82~80	18~20
Digested sludge	-	2.2~2.4	2.1~2.7		-	85~80

3. Results and Discussion

3.1 batch culture experiments

When the wasted cooking oil was not added and initial moisture content was 65%, temperature in the reactor and CO[2] concentration in exhaust increased gradually to 37.5℃ and 2.5% at the 2nd day. Then they decreased to 32℃ (almost room temperature) and 0.3% at 5th day. At that point, the moisture content of reactor increased to 70% and the reaction was all stopped6, 11). There might be two reasons that :(1) the calories

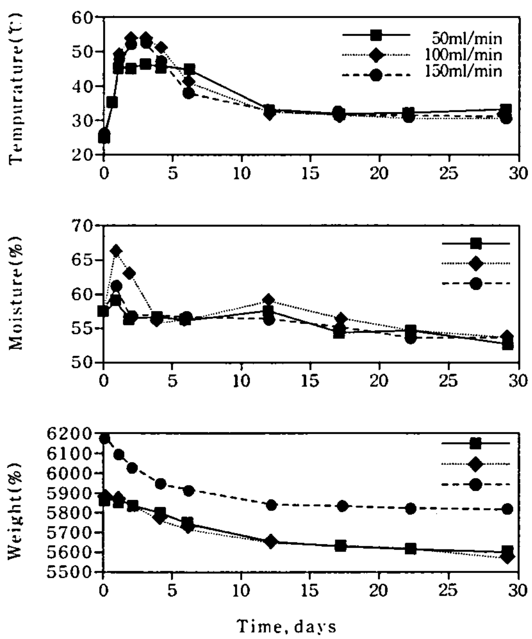

Fig. 2. Change of temperature, moisture, weight in batch culture

emitted from degradation of micro algae was not sufficient to evaporate moisture produced by reaction, and the moisture was accumulated in reactor, finally resulted in the reach on stopping. (2) microorganism's activity retrograded due to accumulated moisture7). Therefore, the following experiments were designed with wasted cooking oil used as heating source for evaporation. In the new experiments, moisture content of cedar chips was kept at 55% and air flow rate was changed to 50 ml/min, 100 ml/min, 150ml/min, respectively.

Fig.2 shows the changes of temperature, moisture content and weight decrease in the reactor. The maximum temperature was lower than 38℃ in control condition. But in the case of adding wasted cooking oil, the temperature increased from 45℃ to 55℃ regardless of air flow rate. At the air flow rate of 100ml/min and 150ml/min, the temperature increased to 55℃ at first 2days, and then gradually decreased, finally downed to 32℃ equal to room temperature at 12th day. But the air flow rate of 50ml/min, the temperamre was not over 45℃. When air flow rate was 100ml/min, the moisture content of the reactor increased to 66% at the first day, and then gradually decreased. But after the 4th day, it kept at 57± 1%. When air flow rates were 100ml/min and 150ml/min, moisture content of reactor was 57± 1%, which is the same levels as beginning. No accumulation of moisture content occurred. The above results well demonstrated that the addition of wasted cooking oil and proper aeration could increase temperature in reactor and contributed to evaporate the moisture[12]. At airflow rate of 1 00ml/min, the weight of reactor decreased to

300g. The degradation rate at the air flow rate of 100ml/min was higher than that for the other two cases.

Fig.3 shows change of concentration of CO_2 and N_2O in exhaust under different air supply conditions. The CO_2 concentration increased up to 3.5% at initial stage when material degradation is active. but decreased gradually, and finally downed below 1%. Among the three air flow rates. the produced CO_2 concentration at 100ml/min air flow rate was slightly higher than that of others two flow rate. N_2O gas was increased to 3~3.5 ppm at initial stage, but then decreased rapidly, finally was below 0.3 ppm. And so it could be concluded that N_2O concentration was not affected by air flow rate. CH_4 was detected at just only starting stage. It suggested that CH_4 could not be detected in the condition of sufficient aeration.

3.2 continuous culture experiments

Fig.4 shows variation of concentration of CO_2. N_2O and CH_4 of exhaust in continuous experiments. In steady-state, CH_4 was not detected through the experiments. CO_2 and N_2O emissions were not affected by the methods(with PAC or without PAC) of substrate dewatering. It meant that PAC addition for dewatering had no influence on CO_2 and N_2O emissions. Then experiments were conducted to elucidate the influence of medium kinds on N_2O emission. Cedar chips, by-product of sawing in forest industry, which was widely used for composting together with straw and rice bran. Comparatively the reed is now using as one of effective water plants for purification in polluted and eutrophic lakes or rivers. In this experiment, the potentiality of reed as a media material was examined in thermophilic oxic process or composting. There was no difference in N_2O emission whether cedar chips or reed chips was used. As a result, since the reed chips was useful, and could be recycled, much study are needed to

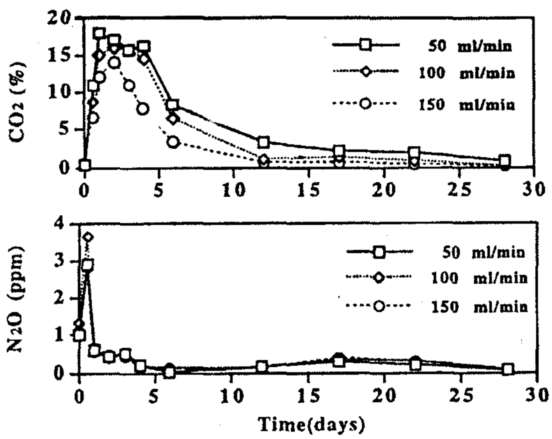

Fig. 3. CO, N_2O concentration in batch culture

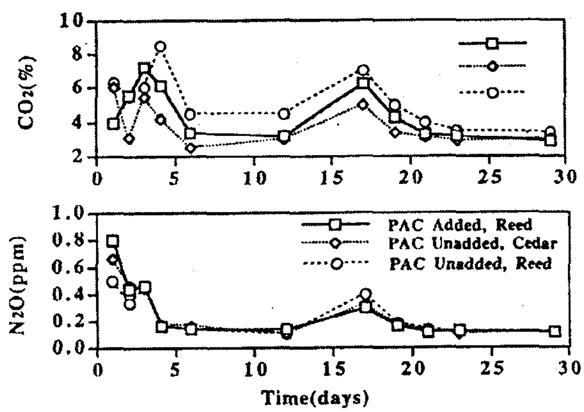

Fig. 4. CO_2, N_{2O} concentration in continuous culture

test the use and potentiality of water plants (ex. water hyacinth) as new recycling resource.

4. Conclution and Prospect

This study was carried out to establish the effective conditions of N_2O and CH_4 control in thermophilic oxic process. And results showed that: 1) CH_4 was not generated when aeration was sufficient enough. 2) N_2O concentration was not affected by aeration 3) N_20 and CO_2 concentrations were not affected by dewatering-methods or media kinds, and therefore the reed can be used as new media material.

From this study, thermophilic oxic process can be operated under wide conditions if the air supply is sufficient. Studies are needed to transform recycling wasted organic materials of water hyacinth, reed and microalgae into useful resources. At the same time, construction of treatment processes was needed to control N_2O, CH_4 emission from facilities. Further study is needed to test both treatment conditions such as mixing rate, organic loading, etc., and substrates such as livestock sludge, water plant, sludge from household purification facility, etc. Much small livestock farms exit in our country. But now the waste/wastewater produced from these places are not treated properly. And so, this process maybe useful in especially rural area.

References

1) Osayuki, Y., Gerald G. S., William, L., and Masayuki, H.,"5th international workshop on nitrous oxide emissions", session3,
2) Freney, J. R., Denmead, O. T., and Simpson, J. R., "Soil as a source or sink for atmospheric nitrous oxide", Nature, 273, 530-532(1978)
3) Inamori, Y., Hasomi, M., and Sudo, R., " Greenhouse effect gas control producing from waste water treatment process", water and waste, 33, 28-34(1991)
4) Kenji, Y., Michmasa, T., "Emission of nitrous oxide from waste management system, 5th intenational workshop on nitrous oxide emmssions", session 3,Tsukuba Japan(1992)
5) Kurihara, T amd T. Mori., "Composting sludge with reeds", biocycle, 38-41 (1987)
6) Yang, J. K., Simizu, Y., Choi, S. K., amd Mori, T., "Significance of Calorie/Water ratio in the treatment of highly concentrated organic matter by thermophilic oxic process", J. Jpn. Soc. Wat. Environ, 18, 47-52(1995)
7) Bae, Y. J., "Study on microorganism for composting process, the thesis of doctor degree", Tokyo University(1991)
8) Japan sewage works association., Standard the methods for the examination of sewage, 3rd ed., Tokyo (1984)
9) Fujita, K., Composting technology, 47-50, gibodou press, Tokyo(1993)
10) Fuji technosystem Corp., Strategy book

for fertilization and utilization of sludge, 359-363, Tokyo(1976)

11) Liu, B. G., Noda, S., amd Mori, T., "Complete decomposition of organic matter in high BOD waste water by thermophilic oxic process". Pro. of Environmental Engineering Research, 29, 77-84(1992)

12) Bach, P. D., Nakasaki, K., Shoda, M. and Kubota, H., "Thermal balance in composting operations", J. Ferment Technol, 65, 199-209(1987)