7－1

EFFECT OF ORGANIC LOADING RATE ON AEROBIC BIODEGRADATION OF FECES IN BIO-TOILET SYSTEM

Lopez Zavala Miguel Angel, Funamizu Naoyuki and Takakuwa Tetsuo
Department of Environmental Engineering. Hokkaido University. Sapporo 060-8628, Japan

INTRODUCTION

Aerobic biodegradation of toilet wastes in bio-toilet system is an essential treatment process of the Onsite Wastewater Differentiable Treatment System (OWDTS). In this system, the separation of household wastewater into three types is essential; thus, reduced-volume black-water, higher-load graywater and lower-load graywater have been identified (Lopez *et al*, 2001). The OWDTS is supported by environmental and health principles such as: ecological sanitation, ecologically sustainable development, resources recycle (nutrients and water), water cycle management, total catchment's management, conservation of water resources, protection of public health and the prevention of public health risk (Ulmarra Shire Council, 1998).

Aerobic biodegradation of toilet wastes in bio-toilet system is influenced by four major factors:

1. Microorganisms for biodegradation (number, type).
2. Substrate quantity and bioavailability (composition, lignin content, particle size, etc.).
3. Nutrients, macro (N, P, K, S) and micro (Mg, Co, etc.).
4. Environmental conditions (moisture, porosity, temperature, oxygen, pH).

As it is known, heterotrophic organisms, mainly bacteria, biodegrade organic matter. Terazawa (1997) found that in systems based on sawdust as a matrix (bio-toilet), bacteria are the microorganisms responsible of aerobic biodegradation. On the other hand, toilet wastes (mainly urine) are rich in nutrients, so that, nutrients availability is not a limiting factor for bacteria growth. Under those considerations, optimum substrate quantity and bioavailability and environmental conditions must be set in order to describe aerobic biodegradation kinetics.

Under above considerations, a research has been undertaken with the purpose of setting the optimum feces/sawdust ratio (F/S), moisture content, temperature, oxygen supply rate and pH. In this paper, results of F/S ratio evaluation are shown.

METHODOLOGY

The evaluation of organic load influence on aerobic biodegradation of feces in bio-toilet system was carried out by using the experimental device schematically represented in Figure 1 and regarding the conditions described on Table 1.

Batch tests for each F/S ratio were performed. Sawdust was put into the corresponding chamber and aerated with the purpose of eliminating the effect of possible inorganic consumption of oxygen (stabilization of oxygen utilization rate curve, OUR curve). Once stabilization occurred, feces were added to each chamber according to each ratio. Feces and sawdust were perfectly mixed until get a homogeneous feces-sawdust mass. Feces weight was calculated according to eq. (1).

$$WW_f = k\frac{WW_s(1-\theta_s)}{(1-\theta_f)} \quad (1)$$

where WW_f and WW_s are the feces and sawdust weights on wet basis, k is the F/S ratio (decimal) and θ_f and θ_s are the feces and sawdust moisture contents.

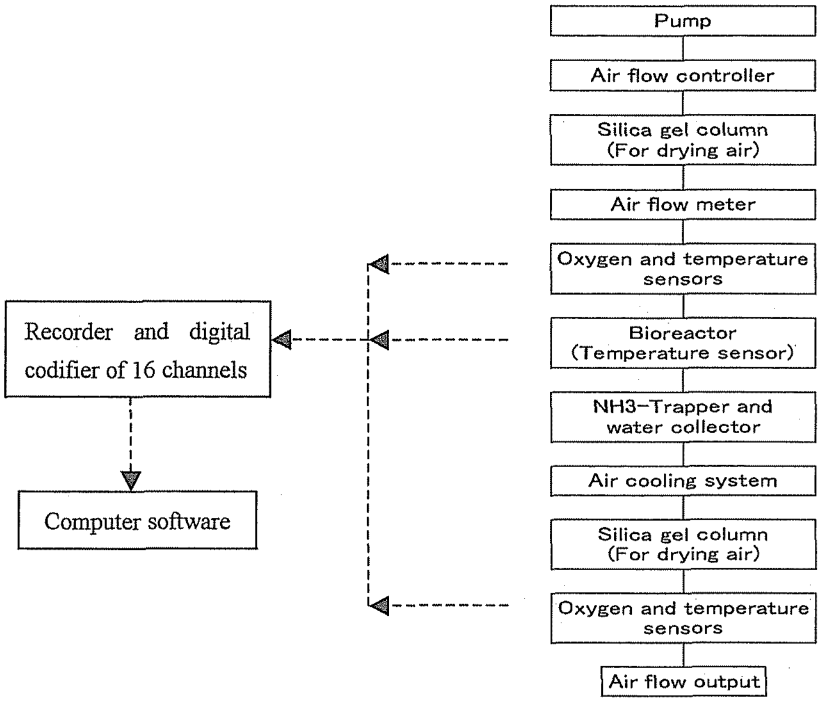


Figure 1. Schematic representation of experimental device.

Table 1. Experimental conditions for evaluation of organic load influence on aerobic biodegradation of feces in bio-toilet system.

F/S* (%)	TS feces[1] (g)	TS sawdust[1] (g)	Temperature (°C)	F-S θ_{Initial} (%)	θ_{feces} (%)	θ_{sawdust} (%)	Air flow rate (ml/min)
5	6.3	125.0	55.0	60.0	80.4	21.0	50.0
10	12.5	125.0	55.0	60.0	84.7	21.0	50.0
15	18.8	125.0	55.0	60.0	73.4	21.0	50.0
20	25.0	125.0	55.0	60.0	82.3	21.0	30.2
25	31.2	125.0	55.0	60.0	83.8	21.0	100.0

1. On dry basis.
* F/S ratios (dry basis) were fixed based on empirical information gotten by Terazawa (1997) and trying to explore a probable practical range.

Batch tests were stopped when the OUR curve for each case became stabilized, approximately 2 weeks after starting them. OUR was monitored every 30 minutes in all trials; additionally, other parameters such as TS (total solids), VS (volatile solids), COD, T-N (total nitrogen), NH_3-N, NO_3-N, Cl, PO_4-P, SO_4, θ (moisture content), EC (electrical conductivity), and pH of feces, sawdust and compost (biodegradation product) were measured for each trial. TS, VS were measured gravimetrically adopting the well-known procedures. θ was calculated from gravimetric determinations. EC and pH were measured from sawdust and compost extracts using the corresponding apparatus. COD was evaluated by using a standard method for wastewater analysis with some modifications to ensure precise determinations due to solid samples were managed. T-N was determined by using Kjeldahl method. NH_3-N was measured by colorimetry. Water released from the system and its NH_3-N concentration was also quantified in all trials. NO_3-N, Cl, PO_4-P, and SO_4 of feces, sawdust and compost extracts were determined by using ion chromatography.

RESULTS

OUR profiles

Figure 2 shows the OUR patterns for each F/S ratio. OUR profiles started near zero to increase and decrease rapidly within a period of 48 hours (2 days), reaching the maximum approximately 8 hours after starting the test. OUR profile of F/S ratio 20 showed different behavior due to oxygen was a limiting factor. For this reason, this ratio was not considered on below analysis. As can be seen, peak of F/S ratio 10 was higher than that of F/S ratio 15, moisture content and then mixture conditions seem to be responsible of lower OUR peak and profile retardation. After 72 hours (3 days), OUR profiles decreased gradually reaching stable state approximately at 240 h (10 days). End of biodegradation process for each trial was affected by the supplied airflow rate. Higher airflow rate caused drying of sawdust and consequently faster end of bio-reactions. The fact that the initial OUR was near zero means that the initial biomass (bacteria) activity was very low or negligible. This issue seems to be clear due to low moisture content (21%) and low temperature (under refrigeration) at which was kept the sawdust. So, bacteria activity started once environmental conditions were proper for their growth.

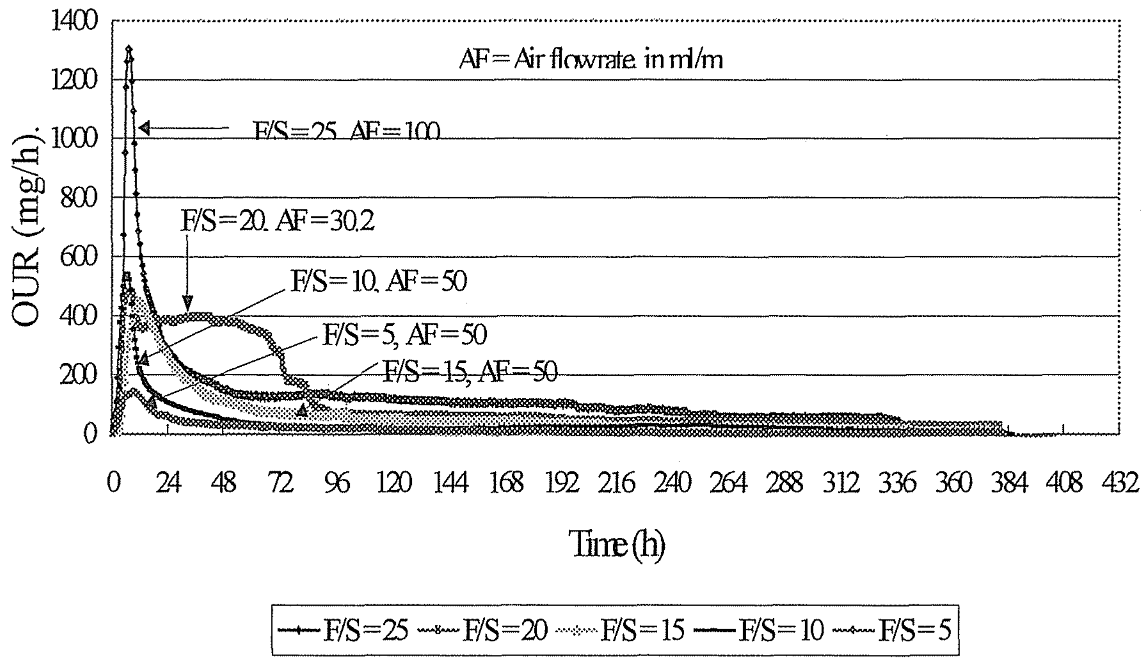


Figure 2. Respiration rate profiles (OUR) obtained for five different F/S ratios.

Biodegradation of organic matter

Figure 3 shows the effect of organic load on TS reduction. TS reduction increased linearly as the F/S increased and approximately 56% of feces, in terms of TS, was reduced in all organic loads (F/S ratios) evaluated as it can be read from the Figure 3.

In Figure 4, the effect of organic load on VS reduction is shown. In general speaking, the profiles gotten are similar to those of TS reduction. VS reduction also increased almost linearly as the F/S ratio increased; however, in this case the reduction of feces in terms of VS was approximately 70%.

Similarly to TS and VS, COD profile showed an increasing tendency as the F/S increased; however, redaction was about 75% respect to the COD of feces (Figure 5), it means, the biodegradation rate of feces was 75% in spire of the redaction rate of VS and TS was lower.

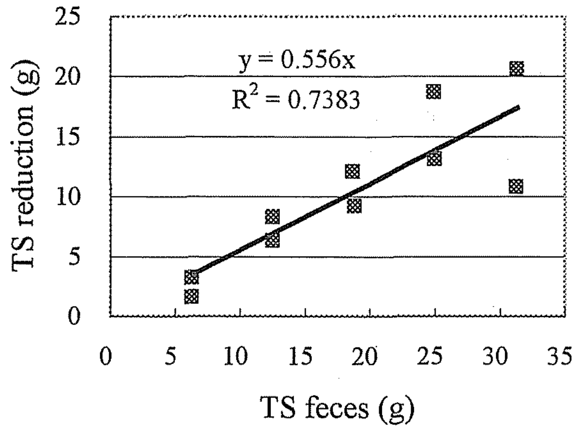


Figure 3. Effect of organic load on TS reduction.

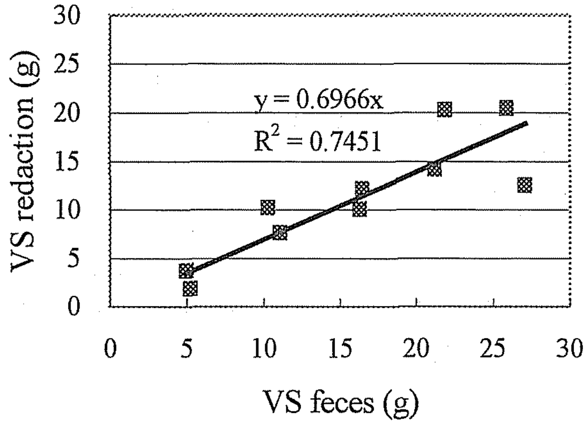


Figure 4. Effect of organic load on VS reduction.

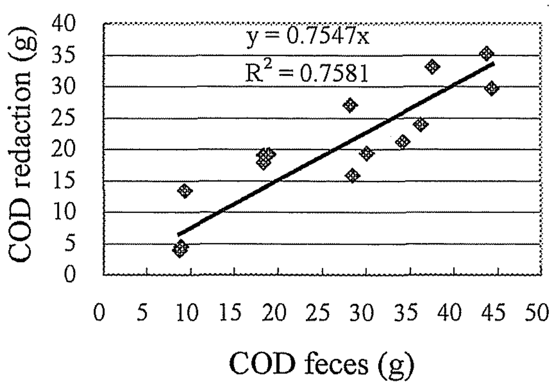


Figure 5. Effect of organic load on COD redaction.

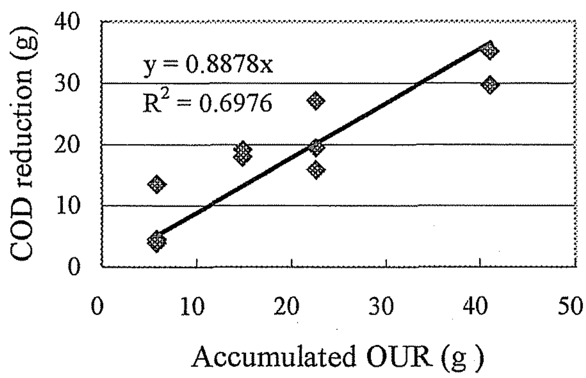


Figure 6. Relationship between accumulated OUR and COD reduction for several organic loads.

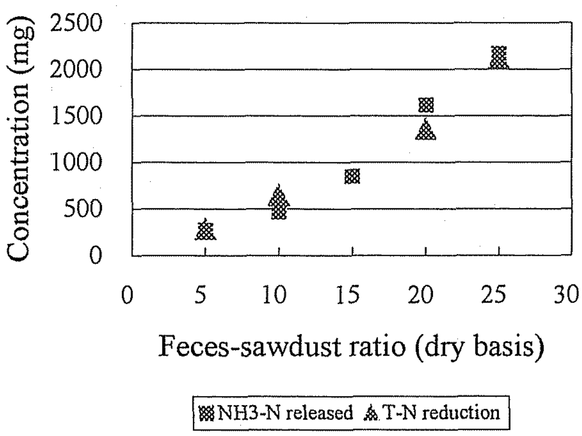
In this experiment, constant weight of sawdust was used, and organic load was controlled by the amount of supplied feces. From above results, it seems to be clear that organic load (F/S ratio) is not a limiting factor for aerobic biodegradation of feces in bio-toilet system, at least in a practical range and under the environmental conditions fixed during the experiment performance. It was observed that sawdust was not biodegraded by bacteria under the performance conditions of batch test, i.e., high temperature and short period of time; so that, biodegradation took place only in feces.

Respirometry is the measurement and interpretation of the biological oxygen consumption rate under well-defined experimental conditions. Because oxygen consumption is directly associated with both biomass growth and substrate removal, respirometry could be a useful technique for modeling and operating the aerobic biodegradation of toilet wastes in bio-toilet system.

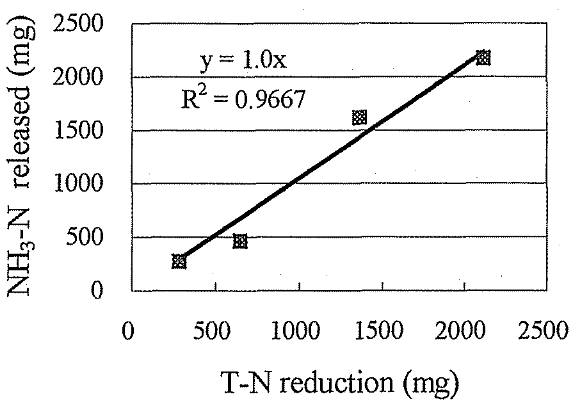
Figure 6 depicts accumulated OUR versus COD reduction, theoretically both parameters should be the same; in fact, it could be assumed such condition occurred even though COD reduction was approximately 89% of the accumulated OUR. Difficulties to monitor very low OUR values, set the end of bio-reactions and errors associated to COD determinations may be the explanation of that difference. Despite such difficulties, OUR may be employed to describe biokinetic characteristics of aerobic biodegradation of toilet wastes in bio-toilet system.

Nitrogen

Regarding the processes in which the nitrogen is involved, it was found that ammonification process occurred under the conditions at which the experiment was performed (see Figures 7a and 7b). In general speaking, the T-N reduction increased as F/S increased, however, attenuation was observed at F/S ratio 25, where the NH_3-N reduction was important. Organic load variation did not have a clear effect over NH_3-N reduction; in fact, it was very low in most cases. NH_3-N was importantly released to the atmosphere and that increased as F/S ratio increased; in fact, the sum of T-N reduction and NH_3-N reduction was equivalent to the NH_3-N released to the atmosphere (Figure 7b). This issue reveals that nitrogen transformations were only associated to ammonification. Despite fractions of nitrates were found in feces, sawdust and compost samples, their concentrations were so low to be considered as a sign of occurrence of other processes related to nitrogen such as denitrification.



a)



b)

Figure 7. Effect of organic load on T-N reduction.

Moisture content, pH and EC

Moisture content decreased considerably in those trials where high airflow rates, respect to the organic load, were supplied (F/S ratios 5 and 10), so that, lower airflow rates must be used to avoid drying and consequently incomplete biodegradation. pH increased a little in most trials from 7.6 to more than 8. EC also showed an increase during biodegradation reaching values near 6 mS/cm in most cases when the tests were stopped. Other parameters did not show clear tendency respect to organic load variation.

CONCLUSIONS

1. Accumulated OUR and COD determinations showed acceptable correlation, so that, OUR may be employed to describe biokinetic characteristics of aerobic biodegradation of toilet wastes in bio-toilet system. Respirometry could be a useful technique for modeling and operating the aerobic biodegradation of toilet wastes in bio-toilet system. OUR profiles will be also very important on characterization of organic matter (toilet wastes).
2. Aerobic biodegradation rate (COD reduction) of feces in bio-toilet system was approximately 75% independently of organic load regarded. Therefore, organic load was not a limiting factor for aerobic biodegradation of feces at least in the practical F/S ratios evaluated. TS and VS reductions on the order of 56% and 70% respectively were observed independently of the organic load regarded. Dynamic evaluation of organic load influence on aerobic biodegradation rates of feces is needed, so that, tests under continue feces adding are required.
3. Ammonification process occurred during aerobic biodegradation of feces, other processes related to the nitrogen cycle were not observed under the experimental conditions at which the batch tests were performed. All T-N reductions in the bioreactor were equivalent to the NH_3-N released to the atmosphere.
4. High airflow rates caused drying in the sawdust matrix, so that, influence of aeration rates and moisture content on the aerobic biodegradation of feces must be investigated. At the same time, biodegradation rates under different temperatures must be also evaluated.
5. Increases of pH and EC were observed during the performance of batch tests, so that, effect of these parameters on biodegradation rates could be evaluated.

REFERENCES

1. Almeida M.C, Butler D. and Friedler E. (1999). At-source domestic wastewater quality. Urban Water 1, pp 49-55.
2. Ayres Associates (1998). Technology assessment of onsite wastewater treatment systems (OWTS). Monroe County Sanitary Wastewater Master Plan. Florida, USA.
3. Garland J. L., Levine L. H., Yorio N. C., Adams J. L. and Cook K. L. (2000). Graywater processing in recirculating hydroponic systems: phytotoxicity, surfactant degradation, and bacterial dynamics. Wat. Res. Vol. 34, No. 12, pp. 3075-3086.
4. Lopez Zavala M. A., Funamizu N. and Takakuwa T. (2001). Onsite wastewater differentiable treatment system: modeling approach. Paper accepted to be presented in the IWA-World Water Congress Berlin 2001.
5. Ohio State University (1999). Bulletin 604. Ohio livestock manure and wastewater management guide.
6. Stephenson T. and Judd S. J. (2000). In-building wastewater treatment for water recycling. School of Water Sciences, School of Industrial and Manufacturing Science. Cranfield University, UK.
7. Terazawa M. (1999). Establishment of forestry, agricultural, and fishery biomass waste recycling system. Division of Environmental Resources, Graduate School of Agriculture, Hokkaido University, Japan.
8. Terazawa M. (1997). Biological cleanup and recovery of organic wastes using sawdust as an artificial soil matrix. Division of Environmental Resources, Graduate School of Agriculture, Hokkaido University, Japan.
9. Ulmarra Shire Council (1998). Director Environmental Services Report. Onsite sewage management discussion paper. Australia.
10. Ward R. C. and Englehardt J. D. (1999). Management of decentralized, on-site systems for treatment of domestic wastes. Agricultural & Biological Engineering Department, Purdue University, West Lafayette, IN 47907-1146.