THERMOPHILIC ANAEROBIC WASTEWATER TREATMENT

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Abstract

The modern society generates large amounts of wastewater that represent a tremendous threat to the environment and both human and animal health. The choice of method must always be based on maximum safety, minimum environmental impact and, as far as possible, on valorization of the waste and final recycling of the end products. One of the main trends of today's waste management policies is to reduce the stream of waste going to landfills and to recycle the organic material and the plant nutrients back to the soil.

In this paper recent achievements are discussed regarding the process stability of thermophilic anaerobic wastewater treatment systems. Thermophilic process offers many benefits: the physical, chemical and biological characteristics of this process are unknown.

Keywords: anaerobic treatment, thermophilic, wastewater, biogas

INTRODUCTION

Within the last two decades, anaerobic processes have become an attractive alternative to aerobic treatment for treating moderate to high-strength. Many researches have been conducted for the effect of temperature variation under mesophilic, thermophilic, and even psychrophilic conditions for the treatment of low-strength and high-strength wastewater.

Many industrial effluents, such as those from food processing, textile industry, paper and pulp industry are often discharged at elevated temperatures. Treating these organic rich effluents under conventional mesophilic condition requires pre-cooling, and has the risk of losing the biomass activity if the cooling system breaks down (*Zhang et al., 2003*). Under these circumstances, where the wastewater is present at an elevated temperature, thermophilic treatment systems are more applicable as the energy and cost required for increasing the bioreactor operating temperature is not required (*Sindhuja Sankaran*).

1. THERMOPHILIC ANAEROBIC WASTEWATER TREATMENT

Anaerobic digestion of food wastes becomes a promising treatment technology as well as production of methane biogas for energy recovery. Anaerobic digestion is a multistage biochemical process in which complex organic substances are fermented by microorganisms in the absence of oxygen. The most important product formed in anaerobic digestion is biogas, a renewable energy source, which can be used as vehicle fuel, for both heating and electricity production. The composition of biogas depends on the composition of the inflow substrate, the microorganisms present and the factors that affect the stabilization process. As far as the substrate chemical composition is known, the composition of biogas can be approximately calculated by the following formula:

$$CaHbOcNdSe + (a\text{-}b/4\text{-}c/2\text{+}3d/4\text{+}e/2)\ H_2O \rightarrow (a/2\text{-}b/8\text{+}c/4\text{+}3d/8\text{+}e/4)\ CO_2$$
$$+$$
$$(a/2\text{+}b/8\text{-}c/4\text{-}3d/8\text{-}e/4)\ CH_4 + d\ NH_3 + e\ H_2S$$

Biogas generally consists of methane – CH_4 (55–70%,), carbon dioxide – CO_2 (27–44%) and others that are considered trace gases; hydrogen sulphide -H_2S (up to 3%) and trace gases usually below limit of detection (NH_3 - ammonia, CO –carbon monoxide, N_2 – nitrogen)

The process can be divided into steps (Figure 1).

Proteins, lipids, carbohydrates and other complex organics are solubilized by hydrolysis. These hydrolysis products are then converted to short chain organic acids and alcohols. The first two steps together are sometimes referred to as the acid forming stage. These are then converted to methane, carbon dioxide and other trace gases by the methane forming bacteria. This step is referred to as the methane forming stage or methanogenesis.

Successful digestion requires a balance between the production and consumption of intermediates in the three stages of anaerobic digestion. In the first stage breakdown of complex organics (mostly cellulose) to organic fatty acids is slow, even though microorganisms that provide the enzymes to catalyze this breakdown grow quickly. The microorganisms grow fast and break down the fatty acids quickly. In the third stage, methane-forming bacteria grow slowly and are relatively sensitive to environmental factors. Therefore the methane forming bacteria in the third stage are the most limiting group of microorganisms. The whole process has to meet the needs of the methane forming bacteria. The goal should be to maintain the highest level of degradation without sacrificing overall process stability, an equilibrium rate of consumption and production of the microorganisms in the rate limiting stage, usually the third stage.

For achieving successful digestion several physical and chemical factors must be considered. The most important physical factor is temperature. In anaerobic digestion there are generally two temperature ranges. Anaerobic sludge digestion can occur in the mesophilic range (30 - 40 °C), which is more common or in the thermophilic range (45 – max. 70°C), which is less common. Temperature has a considerable impact on various biological and physical factors of the anaerobic conversion process. For instance, the biogas production rate is reduced to a minimum at low temperatures, while it can reach extreme value under thermophilic conditions.

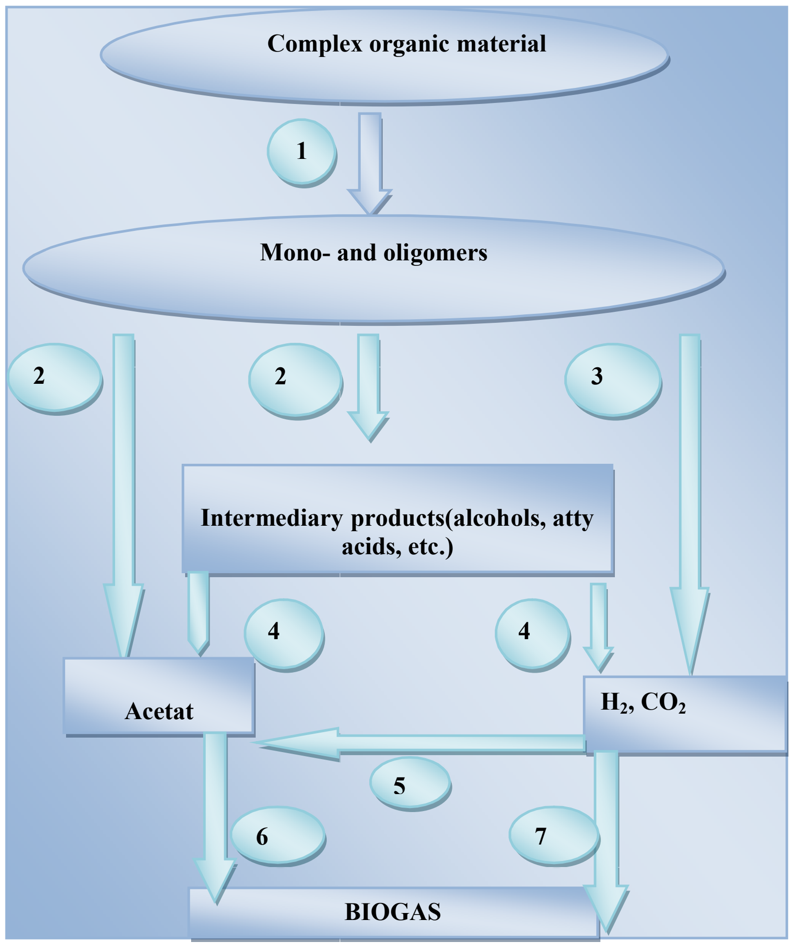

Figure 1. *Steps of methanogenesis in anaerobic digestion*

Several experiments with pure cultures or with complex biomass documented that the thermophilic, non-methanogenic and methanogenic populations have different requirements with respect to the optimum growth temperature.

The effect of a temperature increase from 55 to 65 ^{o}C on process performance and microbial population dynamics was investigated in thermophilic, lab-scale, continuously stirred tank reactors (*Brigitte K.,* *Ahring and al., 2001*). The reactors had a working volume of 3 l and were fed with cattle manure at an organic loading rate of 3 g VS/l reactor volume/d. The hydraulic retention time in the reactors was 15 days. A stable reactor performance was obtained for periods of three retention times both at 55^{o}C and 65 ^{o}C. At 65^{o}C methane yield stabilized at approximately 165 ml/g VS/d compared to 200 ml/g VS/d at 55^{o}C. Simultaneously, the level of total volatile fatty acids, VFA, increased from being below 0.3 g/l to 1.8–2.4 g acetate/l. The specific methanogenic activities (SMA) of biomass from the reactors were measured with acetate, propionate, butyrate, hydrogen, formate and glucose. At 65^{o}C, a decreased activity was found for glucose-, acetate-, butyrate- and formate-utilizers and no significant activity was measured with propionate. Only the hydrogen-consuming methanogens showed an enhanced activity at 65^{o}C. (*Brigitte K., Ahring and al., 2001*)

By comparing two anaerobic filters, one mesophilic(35^{o}C) and one thermophilic(55^{o}C), it was noiced that: at loading rates up to 8.3 kg COD m^{-3} d^{-1}, there was no difference in the performance of the two types of reactor, measured in terms of the removal of soluble COD and gas production. At the higher loading rates of 12.4 and 17 kg COD m^{-3} d^{-1}, the thermophilic filter gave the better performance; The daily methane production from the mesophilic digester was also lower; 3.19 ld^{-1} compared to 4.98 ld^{-1} for the thermophilic digester at the loading rate of 12.4 kg COD m^{-3} d^{-1} and 2.24 ld^{-1} compared to 6.18 ld^{-1} at the loading rate of 17 kg COD m^{-3} d^{-1} (*J.-H.Ahn , C. Forster, 2000*).

Other physical factors, such as mixing, volatile solids loading and hydraulic retention time are also important .

In this range a general VSS removal rate of 40% was reached at low retention times (6 days). At a retention time of 10 days the removal rate was 49%, which is little more than usually reported in conventional mesophilic anaerobic digestion, but at significantly shorter retention time. Specific biogas production (in litres per kg VSS inserted) was higher at longer retention times (3 days – about 400 L/kg, 10 days – about 560 L/kg). However, the fastest biogas production (in liters per day per model) was at 3 days retention time (20.9 L/day per model) (*M. Roš, G. D. Zupančič, 2003*).

CONCLUSIONS

Thermophilic anaerobic digestion offers an attractive alternative for the treatment of medium- and high-strength wastewaters.

The various benefits of the thermophilic treatment system is:

- increased rate of organics degradation
- higher removal of specific compounds
- lower sludge yield

- increased microbial growth rate and rate of diffusion of organics
- higher rate of chemical reactions, specific temperature – dependent enzymes
- higher rate of decay and maintenance energy
- treatment can be operated with shorther hydraulic retention time (HRT) and higher volumetric loading rates (VLR)
- thermophilic wastewater treatment plant can produce better effluent quality
- cost of handling excess sludge is minimized.

REFERENCES

1. Ahn, J.-H., C. Forster, 2000, Comparasion of mesophilic and thermophilic anaerobic upflow filters, Water resources.
2. Ahring, B. K., 1995, Methanogenesis in thermophilic biogas reactors. Antonie Van Leeuwenhoek International Journal of General and Molecular Microbiology, 67.
3. Birgitte K. Ahring , Ashraf A. Ibrahim1 and Zuzana Mladenovsk, Effect of temperature increase from 55 la 60^{o}C on performance and microbial population dynamics of an anaerobic reactor treating cattle manure, Water Resources, vol. 35.
4. Lotta Levén, 2006, Anaerobic Digestion at mesophilic and Thermophilic Temperature, doctoral thesis, Upsala.
5. Roš, M., G. D. Zupančič, 2003, Thermophilic anaerobic digestion of waste activated sludg, Acta Chim. Slov., 50.
6. Wiegant, W. M., J. A. Claassen, G. Lettinga - Thermophilic anaerobic digestion of high strength wastewaters, Water Science and Technology.
7. Wiegant, W. M., J. A. Claassen, G. Lettinga - Thermophilic anaerobic digestion of high strength wastewaters, Water Science and Technology.
8. Wiegant, W. M., J. A. Claassen, G. Lettinga, Thermophilic anaerobic digestion of high strength wastewaters, Water Science and Technology.
9. Zhang, T., Liu, H., and Fang, H.H.P., 2003, Biohydrogen production from Starch in Wastewater under Thermophilic Condition, J. Environ. Management, 69.
10. ***www. public.iastate.edu. Sindhuja Sankaran, Thermophilic Biological Wastewater Treatment, Van Lier J.B., Tilche and al., 2001 – New perspectives in anaerobic digestion, Water Science and Technology, 43.