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Co-digestion of industrial sludge with municipal solid wastes in anaerobic simulated landfilling reactors

Osman Nuri Ağdağ*, Delia Teresa Sponza

Environmental Engineering Department, Engineering Faculty, Dokuz Eylül University, Buca Kaynaklar Campus, Tınaztepe, İzmir, Turkey

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Abstract

The effects co-disposal of industrial sludge with the organic fraction of municipal solid wastes (OFMSW) on the anaerobic treatment of domestic solid waste and the leachate characteristics were investigated in three simulated landfilling anaerobic bioreactors. All of the reactors were operated with leachate recirculation. One of these was loaded only with OFMSW (control reactor); the second reactor was loaded with industrial sludge and OFMSW, the weight ratio of the OFMSW to industrial sludge was 1:1 (dry solid basis) (run 1); the third reactor was loaded with industrial sludge and OFMSW, the weight ratio of the OFMSW to industrial sludge was 1:2 (dry solid basis) (run 2) in order to compare the effects of co-disposal of industrial sludge with the solid wastes. The leachate recirculation rate was 300 ml/day in all of the reactors. pH, chemical oxygen demand (COD), volatile fatty acids (VFA), ammonium–nitrogen (NH_4–N) concentrations in leachate samples; total and methane gas productions in simulated anaerobic reactors were regularly monitored. After 98 days of anaerobic incubation, it was observed that the pH, COD, VFA concentrations in the leachate samples of the industrial sludge-added reactors (especially run 2) were better than in the control reactor. The COD values were measured as 7128, 5714 and 4205 mg/l while the VFA concentrations were 1605, 1310 and 576 mg/l, respectively, in the leachate samples of the control, runs 1 and 2 reactors after 98 days of anaerobic incubation. Although the control has a high initial BOD_5 concentration, the highest BOD_5 decrease occurred in this reactor. The addition of industrial sludge did not significantly retard the decreases in BOD_5 concentrations. The TN, TP and NH_4–N reduction in the control reactor are the highest level. The TN, TP and NH_4–N concentrations in MSW reduced to 614, 314 and 121 from 10 900, 2300 and 500 mg/kg in control reactor by day 98. The values of pH were 6.31, 7.16 and 7.25, respectively, after anaerobic incubation, respectively in the control, runs 1 and 2 reactors. Industrial sludge addition decreased the methane percentage in the anaerobic simulated reactor. The methane percentage of the control, runs 1 and 2 reactors were 31%, 20% and 12%, respectively, after 98 days of incubation. In addition, at the end of the anaerobic toxicity assay (ATA) test, there is significant toxicity in industrial sludge-added reactors (especially run 2) under anaerobic conditions since decreases in methane gas productions was observed.

Keywords: Municipal solid waste; Industrial sludge; Co-disposal; Bioreactor

1. Introduction

The process of anaerobic digestion of the OFMSW, on its own or co-digested with other organic sludges, has the potential to contribute significantly to the renewable energy budget and also to the reduction of landfill or other undesirable waste disposal routes [1].

An interesting option for improving yields of anaerobic digestion of solid wastes is co-digestion [2]. The benefits of the co-digestion include: dilution of potential toxic compounds, improved balance of nutrients, synergistic effect of microorganisms, increased load of biodegradable organic matter and better biogas yield. Additional advantages include hygienic stabilization and increased digestion rate [3]. Co-disposal of MSW and sludge from municipal wastewater treatment plants has a significant effect upon the generation and quality of leachate [4]. Anaerobic digestion of the organic food fraction of municipal solid waste, on its own or co-digested with primary

E-mail address: delya.sponza@deu.edu.tr.
* Corresponding author. Tel.: +90-232-4531008; fax: +90-232-4531153.
E-mail address: o.agdag@deu.edu.tr (O.N. Ağdağ), delya.sponza@deu.edu.tr (D.T. Sponza).

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sewage sludge, produces high quality biogas, suitable as renewable energy [1].

Schmidell et al. [5] reported the anaerobic digestion of MSW mixed with primary sewage sludge. The study was conducted using agitated reactors of 2 or 8 l capacity, continuously operated at 35 °C and in the pH range 6.8–7.2. Results indicated the great interest in achieving anaerobic digestion of MSW in the presence of sewage sludge, utilizing reactors with a high solid content.

Sosnowski et al. [3] presented the results of the investigation of methane fermentation of sewage sludge and OFMSW as well as the co-fermentation of both substrates. In the first experiment the primary sludge and thickened excess-activated sludge were fed into the bioreactor. The second co-fermentation experiment was conducted with the mixture of sewage sludge (75%) and OFMSW (25%) in the same bioreactor arrangement. The weight ratio of OFMSW to sewage sludge was 2:1 (dry solid basis). Generally, in the second experiment more biogas was produced due to larger loading of biodegradable organic matter in the feed-stock. The results of the study showed that the anaerobic co-digestion of sewage sludge and OFMSW seems to be an attractive method for environmental protection and energy savings. Similarly, in a study realized by Warith [6] it was shown that the highest degree of settlement was achieved through addition of sludge, where settlements were about 50% within other reactors.

Anaerobic sludge digestion is one of the most difficult and expensive processes in wastewater engineering. The cost of sludge management comprises approximately 35% of the capital cost and 55% of annual operation and maintenance costs of a wastewater treatment plant [7]. In a study performed by Çinar et al. [8], the effect of various wastewater treatment-plant sludges on anaerobic solid waste degradation in simulated landfill reactors was investigated. The wastewater treatment-plant sludges were directly co-disposed with solid waste in the laboratory to determine an alternative method for sludge digestion and disposal. Three types of sludges, including primary settling sludge, secondary settling sludge (waste-activated sludge) and a mixture of primary and waste-activated sludge, were supplied from a municipal wastewater treatment plant located in Istanbul. Four laboratory scale digesters were designed, constructed and placed in a temperature-controlled water bath, and loaded with sludge and a solid waste ratio of 1:7. The results of the study showed that the stabilization of solid waste in the reactor receiving the mixture of primary settling and waste-activated sludges was faster, as indicated by the total gas production and chemical oxygen demand (COD) removal data.

In the study carried out by Bae et al. [9], performances of lab-scale lysimeters were evaluated to develop a new landfill system for the recovery of CH_4 from solid wastes. Lysimeters were operated at three different conditions: control (L-control), leachate recycle (L-recycle), and sludge recycle (L-sludge). After 430 days of operation, the amounts of COD recovered by CH_4 were 0.13, 0.29, and 22.5 kg for L-control, L-recycle, and L-sludge, respectively. For L-sludge, 77% of total COD outflow was recovered as CH_4 from L-control and L-recycle. Stabilization of organics in L-sludge approached completion within 430 days, while other lysimeters still produced leachate with high COD. Results indicated that the continuous addition of active methanogenic population from the anaerobic digester rather than simple leachate recycle was effective for the rapid and significant CH_4 recovery from solid waste.

Although many of the studies performed related to co-disposal of OFMSW with sewage sludge [10–12], the studies concerning about the co-disposal of OFMSW with industrial sludge are limited. Landfills are employed for solid and hazardous waste disposal throughout the world. Unfortunately, many of these have not been properly designed and operated. For instance, Pohland and Gould [13] studied the effects of co-disposal of municipal refuse and industrial waste sludge in landfills. Four simulated landfill columns were constructed to investigate and detail the consequences of co-disposal of municipal refuse with industrial waste sludge. One column served as the control landfill and received 400 kg of municipal refuse of residential origin. The test columns (Columns 2, 3 and 4) received 400 kg of refuse plus 33.6 kg, 65.8 kg and 135.2 kg of metal plating sludge, respectively. In terms of conversion of COD and VFA, leachate from the control column was rapidly depleted in concentration, suggesting a normal sequence of refuse stabilization with some evidence of conversion of less readily available substrates during the terminal phase. A similar but somewhat delayed pattern of conversion was indicated for Column 2, suggesting that the lowest metal sludge loading tended to impede but not inhibit the conversion of readily available organic compounds. In contrast, both COD and VFA analysis for the leachates from Columns 3 and 4 indicated a definite inhibition of the normal progress of refuse stabilization.

Therefore, the purpose of this research was to evaluate the effects of co-digestion of industrial sludge with municipal solid waste on the COD removal, VFA accumulation and pH variation in leachate samples and methane gas productions in laboratory scale simulated anaerobic landfilling reactors through the degradation of organic fraction of solid wastes collected from the kitchen of the Engineering Faculty in Dokuz Eylul University Campus, İzmir, Turkey.

2. Materials and methods

2.1. Lab-scale simulated landfilling bioreactors

To treat industrial sludge, mixed with municipal solid wastes and to collect the biogas produced stainless-steel cylindrical bioreactors having 10 cm of diameter and 30 cm of height were constructed. The schematic configuration of these reactors is shown in Fig. 1. These bioreactors were operated in batch mode at a temperature of 35–40 °C under