International Journal of Civil Engineering and Geo-Environmental

Journal homepage: http://ijceg.ump.edu.my
ISSN: 21802742

Energy recovery by anaerobic co-digestion of municipal solid waste and sewage

Anwar Ahmad[1*], Rumana Gufran[1], Muhammad A Latif[1], Mimi Sakinah[2], Roslina Omar[1], Zularisam Ab Wahid[1]

[1]Faculty of Civil Engineering & Earth Resources, University Malaysia Pahang, Kuantan, 26300, Malaysia.*email: aanwar@ump.edu.my
[2]Faculty of Chemical Engineering & Natural Resources, University Malaysia Pahang, Kuantan, 26300, Malaysia

ARTICLE INFO

Keywords:
Biogas, Biomethanation,
COD, MSW
co-digestion

ABSTRACT

Waste disposal is one of the major problems faced by all countries. The daily per capita solid waste generated in Malaysian varies from 100 gm in towns to 500 gm in cities. It is estimated that about 27.4 million tonnes of Municipal Solid Waste (MSW) per year and 2,145 million litres of sewage water / day are generated in our country. This project work aims at producing biogas by mixing municipal solid waste and sewage and by using semi continuous fed bio-methanation process. The experiment was carried out for 57 days. The MSW and sewage are mixed in the ratio of 1: 2 and fed into the digester once in every 8 days. The quantity of feed is 4 litres on every 8th day of the previous feed. Various parameters like pH, TS, TDS, TVS, COD are tested for every 8 days and biogas evolved are monitored daily over a retention period of 57 days. It is found that the quantity of biogas evolved is 517 litres. Biogas of about 9 litres per days can be generated. It is estimated that 1.18x109 m3 of biogas can be generated annually from 27.4 million tonnes of MSW annually in our country. Thus by utilizing MSW and sewage we can conserve the fossil fuel like coal, oil, etc. Moreover, the environment is protected largely by recycling the waste MSW into useful energy while the residue forms enriched manure to the field.

*Corresponding author

1. Introduction

Waste disposal is one of the major problems faced by all nations across the globe. It takes 3 – 7 days for the waste to be disposed from the time of its generation. Majority of which is dumped in landfills. About 70% of the cities do not have adequate capacity for collection and transportation of MSW. The uncollected waste is left to rot in the open or burnt on road side causing environmental pollution viz. smell, smoke, etc. Mufeed Sharholy et al studied that Municipal solid waste management (MSWM) is one of the major environmental problems of Malaysian cities. Improper management of MSW causes hazards to inhabitants. Various studies reveal that about 90% of MSW is disposed of funscientifically in open dumps and landfills, creating problems to public health and the environment.

Though there are several methods for the conversion of waste into useful energy bio-methanation process is a clean and haste free solution to the problem of solid waste management.

It produces biogas with 70% methane content and rich organic manure. It is with this background, an attempt is made in this work to explore the biogas yield potential by anaerobic co-digestion of MSW and sewage in proportion of 1:2.

The values for volumetric biogas production rate and methane yield increased at higher temperatures. The average volumetric biogas production rate for cyclic operation between 11 and 25 °C was 0.22 Ld^{-1} L^{-1} with a yield of 0.07 m^3 CH_4 kg^{-1} VS added, whereas for operation between 15 and 29 °C the volumetric biogas production rate increased by 25% (to 0.27 $Ld^{-1}L^{-1}$ with a yield of 0.08 m^3 CH_4 kg^{-1} VS add). In the highest temperature region a further increase of 7% in biogas production was found and the methane yield was 0.089 m^3 CH_4 kg^{-1} VS add.

Ye Chen et al. reviewed that inhibitors commonly present in anaerobic digesters included ammonia, sulfide, light metal ions, heavy metals, and organics. Due to the difference in anaerobic inoculum, waste composition, and experimental methods and conditions, inhibition caused by specific toxicants vary widely. Neves et al used synthetic waste to study the effect of waste composition on anaerobic degradation of restaurant waste, A high reduction of volatile solids (between 94% and 99.6%) was obtained in all the assays. The methane yield was between 0.40 m^3 CH_4/kg VS initial (excess of carbohydrates) and 0.49 m^3 CH_4/kg VS initial (excess of lipids).

The degradation of the lipid-rich assays differed from the others. Fifty percent of the biochemical methane potential was obtained after 3–6 days for all of the assays, except for the one with excess of lipids which achieved 50% methanation only after 14.7 days of incubation. In the assay with excess of lipids, a considerable fraction of COD remained in the liquid phase, suggesting an inhibition of the methanogenic process that was likely due to the accumulation of long chain fatty acids. The hydrolysis rate constants, assuming first order kinetics, over the first 6 days were between 0.12 d^{-1} (excess of lipids) and 0.32 d^{-1} (excess of carbohydrates). The results indicate that anaerobic digestion facilities with large variations in lipid input could have significant changes in process performance that merit further examination.

Bhattacharyya et al. found that Biomethanation of municipal solid waste is a slow process and the yield of biogas is usually low. Enhancement of acidification is necessary to increase the biogas yield in biomethanation of MSW. MSW contains a significant fraction of ligno-cellulosic material. Experiments have been conducted to study the effect of recirculation of leachate on the acidification stage of the two-phase biomethanation process. Chemical oxygen demand (COD) and volatile fatty acid (VFA) were considered as indicator parameters. It was observed that daily recirculation of leachate does not have any major impact on the acidification process. It was also observed that treatment of MSW with sodium hydroxide yields leachate of significantly higher COD and VFA values compared to others. Callaghan F.J. et al experimented by mixing cattle slurries with a range of solid wastes and allowed to digest in 1-1 batch digesters. VS reductions (%) has little difference between the various digestions. Co-digestions with fruit and vegetable waste, the fish offal and the dissolved air flotation sludge were more effective than the digestion with cattle slurry alone and specific methane yield the co-digestions containing fish offal and the brewery sludge gave higher values. Compared with their control (cattle slurry alone), both co-digestions with poultry manure (7.5 and 15% TS) gave higher cumulative productions of methane and the system with the lower concentration of poultry manure gave a higher specific methane yield.

Viéitez, E.R. et al describes innovative system consisting of a solid-bed reactor packed with simulated solid waste at a density of 160 kg/m^3 and operated with recirculation of the percolated culture (bioleachate) through the bed. These fermentative reactions stopped after about 2.5 months of solid-bed fermentation at which time total volatile fatty acids (VFA) concentration accumulated to 13,000 mgL^{-1} (as acetic) at pH 5, and the reactor head-gas consisted of 75% carbon dioxide, 20% nitrogen, 2% hydrogen and 3% methane. The VFA concentration and gas composition remained virtually constant for an additional 2.5 months of solid-bed fermentation indicating inhibition of the hydrolysis–acidification process. Inhibition of acidogenic fermentation was alleviated by moving the bioleachate to a separate methane-phase fermenter, and recycling methanogenic effluents at pH 7.5 to the solid bed.

Coupled operation of the two reactors during the following 4.5 months of two-phase fermentation achieved methanogenic conversion of about 30% of the volatile solids (VS) content of the high-solids feed. Traverso developed a pilot scale mesophilic anaerobic acidogenic fermenter fed with mixtures of vegetables and fruits working with a HRT in the range 1–12 days. The effluent coming from the fermenter was screw pressed, and the solid phase was recycled adopting different ratios to the fermenter, in order to define its effect on the final liquid phase composition. The variations of the VFA, lactate, methyl and ethyl alcohol concentrations, TCOD, SCOD and pH during more than one year were analyzed and it was found that almost all the organic matter in the liquid phase inside the fermenter was represented by VFA (mainly acetate), lactate (in particular) and methyl and ethyl alcohols when HRT was longer than 6 days.

2. Materials and Methods

The experiment is based on anaerobic process with semi continuous feeding in 110 l batch reactor. The starting seed, inoculum, for the bio-methanation process are prepared by mixing cow dung and water in standard ratio. The initial feed of 40 litres is kept in the digester under anaerobic condition for 30 days for the growth of methanogenic bacteria. MSW was collected from vegetable market, household waste, hotels, etc. The solid waste is crushed well, mixed with the sewage water and fed into the digester. The purpose of adding sewage with MSW is to dilute the feed, to conserve fresh water to avoid ground water depletion, and prevent recycling of process effluent. Gioannis G.De. et al. mentioned that the integration of the MSW and wastewater treatment cycles, makes it possible to avoid the recirculation of process effluent. Semi continuous feeding of MSW and sewage mixture is done at 4 liters (10 % of initial feeding) once in every 8 days, for one month. This 4 litres feed consists of 1 part of MSW and 2 parts of sewage water.Care should be taken to prevent the entry of air inside the digester as it will stall the growth of methanogenic process. Mixing was done manually by shaking the digester at regular interval of time. The working volume of the digester is 3/4th of the capacity of the tank and remaining 1/4th is kept empty for the collection of gas. The empty space is kept constant by removing the slurry, if the amount of slurry increases above 3/4th of the tank volume. The feeding is varied after one month by 7 days interval.

The gas formed by the biomethanation process at the top of the tank is collected and measured by water displacement method. Several parameters like pH, TS, TDS, TVS, COD etc are tested every week after feeding. Also pH has to be maintained at 8 by addition of NaoH suitably. The biogas is tested by flammability test.

3. Results and discussion

Bio-methanation of MSW and sewage water was carried out in an experimental semi continuous process by mixing in proper proportion (1 : 2) and the biogas potential of the mixture is investigated over a hydraulic retention time of 57 days and optimum conditions of various experiment parameters are reported. The quantity of biogas evolved every day is measured and tabulated in Table 1. Various test parameters like Ph, TS, TDS, TVS, COD, etc are calculated after every feeding which is given in table 2. From the experiment conducted on the semi continuous fed biomethanation
process with MSW and Sewage, the following salient features are summarized:

Table 1: Quantity of Gas Evolved

Sr. No.	Retention time (d)	Evolved gas (L)	Cumulative amount of gas (L)
1	1	0	0
2	8	2.5	2.5
3	16	14.5	50.5
4	24	8.5	85.5
5	32	21	227.5
6	36	31	334.5
7	43	4.5	458.2
8	50	10	517.7
9	57	4	589.2

Biogas generation started after 8 days, shoots up on 10th day and decreased drastically later. This reveals the fact that the methanogic bacteria growth is not rich and hence the feed could not be assimilated by the bacteria. Hence nutrients like K_2HPO_4 and KH_2PO_4 were added to enhance the growth of bacteria. Biogas output peaked on 33 rd day to 31.7 l. and was almost consistent after 52 days. This shows that MSW takes more time to degrade as the contents of MSW were fresh and fibrous during feeding. Sigrid Kusch et al found that Methane yield from fresh material was around 170 LN CH_4 per kg VS added was obtained in Methane production was increased after chopping the substrate and pre-aeration resulted in decreased methane production.

Table 2: Test Results

Retention time, days	MSW + Sewage Feeding litres	Cumulative quantity in digester, litres	pH	COD, mg/l	% COD Reduction	Total Solids, g/l	Total Dissolved Solids , ppm	Total Volatile Solids, g/l
0	4	40	8	5472	0	281.2	2880	12.04
8	4	44	7.83	2912	46.78	480	5440	53.
16	4	48	7.49	2912	46.78	190	7920	32
24	4	52	6.80	3200	41.52	292	7880	40
32	4	56	6.94	560	89.76	684.2	7960	37.5
36	4	60	7.2	480	91.22	1010	8130	30
43	4	64	7.4	530	90.31	1056.7	8320	56.7
50	4	68	6.95	623	88.61	1153	9080	53
57	4	72	7.8	780	85.74	1060.3	8352	60.3

COD of the substrate in the digester reduced well in the beginning for 8 days and then remained constant for next 16 days. It further decreased from 24th to 34 day when the biogas generation peaked. Later COD reduction stabilized and remained in the lowest range till the end of the experiment. This shows the COD reduction has direct impact on the biogas generation. Álvarez et al. treated raw domestic wastewater and found that total suspended solids (TSS), total chemical oxygen demand (TCOD), and biochemical oxygen demand (BOD) removals ranged from 76% to 89%, from 49% to 65%, and from 50% to 77%, respectively, for the overall system. The percentage of influent COD converted to methane was 36.1%, the hydrolysis of influent volatile suspended solids (VSS) reached 59.7% and excess biomass was 21.6% of the incoming VSS. Volatile solids increased in the first 8 days then decreased considerably in correlation with the biogas generation potential and then increased after 40 days time. Hence biogas generation depends on volatile solid contents and reduction. Gioannis G.De. et al showed that the supplying of facultative biomass, drawn from the wastewater aeration tank, to the solid waste acidogenic reactor allows an improvement of the performance at a relatively short hydraulic retention time in the methanogenic reactor, as well as high values of organic loading rate. Significant VS removal efficiency and biogas production were achieved. Moreover, the methanogenic reactor quickly reached optimal conditions for a stable methanogenic phase.

The pH value has to be constantly monitored as there is a steep fall in pH with the beginning of methanogenis process. Therefore pH has to be maintained near 8 always. The total solid content increases gradually upon loading digester with MSW slurry. The TS gets stabilized after 40 days. The total dissolved solids are also stabilized after 40 days of retention time.

4. Conclusion

This research was found that ultimate biogas production potential of municipal garbage was found to be 0.661 m^3/kg volatile solids. The ultimate bio energy yield, ultimate anaerobic biodegradability of the substrate and the overall bioprocess conversion efficiency were evaluated from observations to be 18,145 kJ kg^{-1} volatile solids, 89.79 and 95.44%, respectively. The total biogas yield from municipal garbage per kg dry matter was observed to be 0.5 m^3 and the average methane content of the biogas was observed to be 70 %vol. In this project, it was found that the quantity of biogas evolved is 0.517 m^3 over a period of 57 days. About 9 litres of gas per day can be generated from 36 litres of feed containing 1/3 rd of MSW.

The quantity of MSW available in our country is 27.4 million tonnes per year, from which it is possible to generate 1.18x109 m^3 of biogas annually. Thus by utilizing MSW and sewage, we can equate the fossil fuel like coal, oil etc. largely. As the fossil fuel is fast depleting, this method via bio-methanation of MSW and sewage can be widely adopted to tap biogas, which is a renewable form of energy. In addition, largely recycling the waste MSW into useful energy, while the residue is sent to farm fields as enriched manner protects the environment. Thus, this process has multiple benefits of tapping energy from waste, using sewage for dilution to conserve ground water, avoiding effluent recycling, enriching the soil by using the sludge as manure.

5. References

Bhattacharyya J.K., Sunil K and Sukumar D, (2008) Studies on acidification in two-phase biomethanation process of municipal solid waste, Waste Management, 28-1, 164-169.

Callaghan F.J., Wase, D.A.J. Thayanithy, K and Forster, C.F. (1999) Co-digestion of waste organic
solids: batch studies, , Bioresource Technology, 67-2, 117-122.

Chanakya H.N, Isha S and Ramachandra, T.V. (2009) Micro-scale anaerobic digestion of point source components of organic fraction of municipal solid waste, Waste Management, 29 - 4, 1306-1312.

Gioannis G.D, Diaz, L.F. Muntoni, A and Pisanu, A., (2008) Two-phase anaerobic digestion within a solid waste / wastewater integrated management system, Waste Management, 28-10, 1801-1808.

Álvarez, J.A. Armstrong, E. Gómez, M and Soto, M. (2008) Anaerobic treatment of low-strength municipal wastewater by a two-stage pilot plant under psychrophilic conditions, Bioresource Technology, 99-15, 7051-7062.

Rao, M.S. Singh, S. P. Singh, A. K. and Sodha, M. S. (2000) Bioenergy conversion studies of the organic fraction of MSW: assessment of ultimate bioenergy production potential of municipal garbage, Applied Energy, 66- 1, 75-87.

Mufeed, S. Kafeel, A. Gauhar, M. and Trivedi, R.C. (2008) Municipal solid waste management in Indian cities – A review, Waste Management, 28- 2, 459-467.

Traversol, P. Pavan, P. Bolzonella, D. Innocenti, L. Cecchi, F and Mata-Alvarez, J. (2000) Acidogenic fermentation of source separated mixtures of vegetables and fruits wasted from supermarkets, Biodegradation 11: 407–414, 2000.

René A. and Gunnar L. (2008) The effect of temperature variation on biomethanation at high altitude, Bioresource Technology,99-15, 7278-7284.

Sigrid, K.. Hans, O and Thomas, J. (2008) Biogas production with horse dung in solidphase digestion systems Bioresource Technology, 99-5, 280-1292.

Viéitez, E.R and Ghosh, S. (1999) Biogasification of solid wastes by two-phase anaerobic fermentation, Biomass and Bioenergy, 16-5, 299-309.

Ye, C. Jay, J. Cheng, Kurt, S and Creamer, (2008) Inhibition of anaerobic digestion process: A review, Bioresource Technology, 99 -10, 4044-4064.