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ORIGINAL PAPER

Anaerobic co-digestion of sanitary wastewater and kitchen solid waste for biogas and fertilizer production under ambient temperature: waste generated from condominium house

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Abstract Addis Ababa is one of the fastest growing cities where high urbanization has become a challenge. Consequently, housing shortage is a big problem of the city. The municipality has launched a huge Condominium Housing Programme in response to the problem. However, sanitary wastewater and solid waste management are the critical problems to those houses. The wastes were collected and evaluated for its biogas production and fertilizer potential to solve the foreseen waste management problems. The physicochemical characteristics of the collected wastes were determined. A laboratory scale batch anaerobic co-digestion of both wastes with different mix ratio of 100:0, 75:25, 50:50, 25:75, and 0:100 by volume [sanitary wastewater (TS = 7,068 mg/L):kitchen organic solid waste (TS = 56, 084 mg/L)]were carried out at ambient temperature for 30 days. The amount of biogas and methane produced over the digestion period for those mixing ratios were compared. The highest biogas yield obtained from a mix ratio of 25:75 was 65.6 L, and the lowest from a mix ratio of 100:0 was 9.5 L. The percentage of methane gas in the biogas was between 19.8 and 52.8 %. From the study results, it is evidenced that the mixing ratio 25:75 produced the maximum quantity of biogas and methane. With regard to the fertilizer potential of the digested sludge, composting and sun drying process were helpful for land application by inactivating the pathogen.

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Introduction

Addis Ababa, Ethiopia, with a population of over 3 million generates a large volume of wastewater and more than 200,000 tones/year of solid waste of which 60 % is organic (AACA 2010). The rapid population growth resulted in shortage of affordable housing unit. More than 80 % of the populations are living in a shabby house, poor sanitation condition and less efficient service for waste management (Yenoinshet 2007). The city administration has decided to tackle the challenge of housing by supporting the construction of a massive and relatively low cost housing programme called condominium house. Currently in 119 sites, 77,430 houses have been built and transferred to the city beneficiaries. This programme has brought a significant change in the image of the city, improving the way of life of city dwellers. It also has technical and economic advantages due to the high population density with small area and different job opportunities for large number of people (AACHA 2006).

However, still there is a challenge in the programme such as lack of providing adequate water, sanitation and solid waste management. In the case of solid waste management, there are no recycling programs to exploit the organic fraction, instead the waste is gathered in a communal container around the house and hauled into the disposal site, which has resulted in odorous environment having negative impacts on human health, especially on children. Additionally, the sewer lines of most condominium houses are connected to central wastewater treatment plant (WWTP), which receive large volume of wastewater beyond the designed capacity.

One of the best options for the treatment of organic wastes is the biological treatment of wastes, anaerobic digestion, which achieves both energy production and waste stabilization. Biogas can be considered as an alternative source of energy when facing an energy crisis. The concept of the alternative energy is to get the other resources to replace or substitute the need of petroleum and to reduce the main issue of global warming (Chaiprasert 2011).

Anaerobic digestion is a process by which almost any organic waste can be biologically transformed into another form, in the absence of oxygen. The diverse microbial populations degrade organic waste, which results in the production of biogas and other energy-rich organic compounds as end-products (Azeem et al. 2011). A series of metabolic reactions such as hydrolysis, acidogenesis, acetogenesis, and methanogenesis are involved in the process of anaerobic decomposition. Despite the successive steps, hydrolysis is generally considered as rate limiting. The hydrolysis step degrades both insoluble organic material and high molecular weight compounds such as lipids, polysaccharides, proteins and nucleic acids, into soluble organic substances (e.g., amino acids and fatty acids). The components formed during hydrolysis are further split during acidogenesis, where volatile fatty acids are produced by acidogenic (or fermentative) bacteria along with NH_3, CO_2, H_2S and other by-products. In acetogenesis process, third step, higher organic acids and alcohols produced by acidogenesis are further digested by acetogens to produce mainly acetic acid as well as CO_2 and H_2. The final step of anaerobic digestion, methanogenesis, produces methane by two groups of methanogenic bacteria: the first group splits acetate into methane and carbon dioxide; the second group uses hydrogen as electron donor and carbon dioxide as acceptor to produce methane (Appels et al. 2008).

Co-treatment by anaerobic digestion of different types of wastes such as municipal solid waste, industrial waste, sanitary wastewater, and other biowaste are a common practice for waste management (Westlake 1995; Voutsa et al. 1996; Tang et al. 1997). The process provides improved nutrient balance from a variety of substrates that helps to maintain a stable and reliable digester performance that can steadily generate a high volume of biogas with high methane content. Luostarinen et al. (2008) investigated maximum biogas production at WWTP through co-digestion of sewage sludge with grease trap sludge from a meat processing plant at 95:5 feed on volatile solids basis. Cecchi et al. (1988) and Hamzawi et al. (1998) found that cumulative biogas production of mixtures increased with increasing proportions of municipal solid waste under mesophilic condition. It may be a high biogas and fertilizer yield if the SWW is mixed with KSW instead of disposal. Biogas is generally composed of 48–65 % methane, 36–41 % carbon dioxide, up to 17 % nitrogen, <1 % oxygen, 32–169 ppm hydrogen sulfide and traces of other gases (Azeem et al. 2011). The objective of this study is to produce biogas using anaerobic digestion of sanitary wastewater and kitchen organic solid wastes generated from condominium house at different mixing ratios in laboratory scale experiments. It also investigated the potential use of digested sludge as a fertilizer.

Materials and methods

Raw material and reactor preparation

Both types of wastes were collected from Gotera and Mickililand Condominium House Site, Addis Ababa, Ethiopia. The sanitary wastewater was taken from the sewer line by opening the manhole, while the kitchen organic solid waste was collected selectively from individual households and business houses such as cafe, restaurants, and supermarkets at the site. Lab-scale batch experiments were carried out using cylindrical anaerobic digester. The model of the reactor is W8 issue 3 armfield model. The reactor was equipped with two 5-L packed bed, upward flow reactors, having gas sampling and collection facilities. The temperature of each reactor was controlled by an electric heating mat wrapped around the external wall. The daily gas off-take from each reactor was taken to a volumetrically calibrated collector vessel operating by water displacement. A constant head, liquid seal device ensures that the gas pressure in the reactor was maintained at a constant value throughout the test run. The collected gas was exhausted from the vessel and refilled with water during a test run without breaking the liquid seal. Liquid and gas sampling points were located at all strategic points around the reactors. Non-return valves and liquid seal syphon breaks were included in the process pipe work to ensure each reactor operates at a constant volume without the entrance of air or the danger of accidental syphonic action. The equipment was mounted on a vacuum formed plastic base with an integral drain channel to cope with spillages and wash down (Fig. 1).

Determination of sanitary wastewater and kitchen organic waste characteristics

Before digestion, the collected kitchen organic solid waste was shredded using shredder to an average particle size of 2 mm (physical pre-treatment). Both types of collected raw waste were analyzed for various parameters such as pH, moisture content (MC), total solids (TS), volatile solids (VS), biological oxygen demand (BOD_5), chemical oxygen demand (COD), total nitrogen (TN), total phosphorus (TP), total potassium (TK), organic carbon, total metals and heavy metal (Mn, Na, Cu, Ca, Mg, Pb, Ni, Zn, Fe), total

Fig. 1 W8 issue 3 armfield model anaerobic digester

coliforms (TC), and fecal coliforms (FC). Both wastes were analyzed according to standard methods (APHA 1999).

Co-digestion of sanitary wastewater and kitchen organic solid waste at various mixing ratios

The kitchen organic solid waste was mixed with tap water to maintain the total solid in the digester to 8–10 %, the desired value for wet anaerobic digestion. Then both wastes were mixed at different mix ratios of 100:0, 75:25, 50:50, 25:75, and 0:100 by volume [sanitary wastewater (TS = 7,068 mg/L):kitchen organic solid waste (TS = 56, 084 mg/L)]. Each sample mix was stored in a refrigerator at 4 °C until used for analysis and for feeding. Inoculums sludge was also prepared from cow manure and was mixed with the ratio of 4:1 (feed: inoculums). The reactors were operated under the ambient temperature 25 ± 2 °C and the retention time was about 30 days.

Composting of digested sludge

After the mix ratio based on maximum biogas yield was determined, composting and sun drying process were performed on the digested sludge for 3 weeks to facilitate further use of the digested sludge as a fertilizer and for easy handling. This condition was sufficient to inactivate some of the pathogenic bacteria and helminth eggs (Binod 2008). A circular open plastic container having holes was used for the composting and direct sun drying process. The nutrient contents, heavy metal concentration and coliforms were also analyzed.

Results and discussion

Characteristics of raw sanitary wastewater

The characteristics of raw sanitary wastewater were analyzed (Table 1). From the result, the sanitary wastewater contains considerable load of pollutants and pathogenic microorganism sources that may cause pollution of water and diseases to the community. However, as compared to toilet water concentration (Table 1), the physiochemical characteristics of sanitary wastewater from this study shows lower concentration value in TS, VS, BOD_5, and COD. This might be because, in condominium houses sewerage system, the grey water was mixed with toilet wastewater. Hence, the grey water might dilute the toilet wastewater and ultimately may affect its concentration. This result is also comparable with the finding of Duncan (2004) who reported as “grey water takes the largest percentage of domestic wastewater, and hence, contains relatively small concentration of organic pollutants compared to black water”.

Metals and heavy metals concentration in sanitary wastewater and comparison with standards

Additionally, the concentrations of different metals and heavy metals were also analyzed to determine the suitability of sanitary wastewater from condominium house for biogas production (Table 2). This analysis is used to assure whether a chronic toxicity exists or not for anaerobic microorganism due to the existence of different metal and heavy metal ions. As discussed above in condominium house sewerage system, the toilet wastewater was mixed with the grey water. From these perspectives, there was a fear that condominium house sanitary wastewater might limit the anaerobic microorganism process. The sources of the metals and heavy metals mainly from grey water, since metallic ions and heavy metals were associated with grey water (wastewater generated from domestic activities such as laundry, bathing and kitchen sinks). Grace and Clare (2006) reported a household wastewater might contain different metals and heavy metal contaminants and their major sources were from grey water. According to Grace and Clare (2006), some of the metals found in household wastewater were magnesium, sodium, copper, nickel, zinc, calcium, iron, lead, etc., which may come from a wide variety of chemicals such as detergents, soaps, shampoos, pharmaceuticals soaps, cosmetics, oil, and grease.

Lain et al. (2001) indicated the principal sources of metals in domestic wastewater were body care products, pharmaceuticals, and cleaning products. Human excreta also contribute some loads of (≥ 20 %) of metals such as Zn, Cu, and Ni in domestic wastewater. This different metals and heavy metals might be toxic to methanogenic microorganisms due to the high sensitivity for higher concentration. However, Table 2 compares the result obtained from this study with maximum tolerable limits for anaerobic digestion found in literature. Therefore, it is evidenced that the concentration of different metals and

Table 1 Characteristics of raw sanitary wastewater

Parameters	Unit	Concentration of sanitary wastewater	Black water[a]
pH	–	5.15	7.2–8.8
TS	mg/L	7,068	31,300–87,000
TDS	mg/L	4,794	6,000–22,000
VS	mg/L	4,241	15,000–65,400
COD	mg/L	15,097	36,600–175,000
BOD_5	mg/L	5,586	14,200–52000
TN	mg/L	219.7	700–4050
TP	mg/L	202.7	67.2–98.4
TK	mg/L	120.6	137.1–314.5
TC	MPN/ 100 mL	6.31×10^8	22×10^6
FC	MPN/ 100 mL	7.94×10^5	12×10^6

[a] Isaac (2003)

Table 2 Comparison of the characteristics of condominium house sanitary wastewater with maximum tolerable limit for anaerobic digestion

Substances (mg/L)	Result from present study	Maximum tolerable concentration for anaerobic digestion
Copper	0.28	100[a]
Manganese	1.42	20.0[b]
Nickel	0.365	200–500[a]
Sodium	264.5	3,500–5,500[a]
Calcium	3.53	2,500–4,500[a]
Magnesium	675.8	1,000–1,500[a]
Lead	0.78	2.0[c]
Iron	11.3	20–100[d]
Zinc	1.44	163.0[a]

[a] Metcalf and Eddy (2003)

[b] Medhat and Usama (2004)

[c] Duncan and Nigel (2003)

[d] Jackson and Duncan (1990)

heavy metals in condominium house sanitary wastewater are within the tolerable limits for anaerobic microorganisms and, thus, the wastewater can be treated with anaerobic digestion process.

Characteristics of raw kitchen organic solid waste

The physicochemical characteristics of raw kitchen organic solid waste are shown in Table 3. The amount of volatile solids and organic carbon was higher percentage, while the amount of total nitrogen was relatively small percentage in kitchen organic solid waste. Moreover, the kitchen organic solid wastes are characterized by high percentage of moisture content (>80 %). Luostarinen and Rintala (2006) indicated that kitchen solid waste is rich in nutrients and organic material, and easily biodegradable (>90 % biodegradability). Table 3 also shows the result of the experiment which was compatible with literature data. The higher value of organic carbon and volatile solids indicates that the kitchen organic solid wastes are highly biodegradable and require other wastes containing high macronutrients (nitrogen) such as urine and sanitary wastewater. The characterization results suggest that mixing the kitchen organic solid wastes with other organic feedstock is necessary to provide a nutrient balanced feedstock for anaerobic digestion.

Characteristics of sanitary wastewater and kitchen organic solid waste at different mixing ratios

Table 4 shows the characteristics of sanitary wastewater and kitchen organic solid waste at different mixing ratios. The pH ranged from 6.15 to 7.2. The increasing concentration of TS, VS, BOD_5, and COD as the percentage of kitchen organic solid waste increases, might be due to the highest organic matter content of kitchen organic solid wastes than sanitary wastewater. Claudia (2008) reported the major factors for the increment of TS, VS, BOD_5, and COD might be due to the higher solid content of kitchen organic waste. Considering carbon to nitrogen ratio, Michael (1979) investigated as an important factor affecting the biological process in anaerobic digestion. For anaerobic digestion, an optimum C:N ratio between 20:1 and 30:1 is often suggested. Comparing the C:N ratio of each mixing ratio 100:0 and 75:25 (sanitary wastewater: kitchen organic solid waste) was below the optimum C:N value. This shows that the sanitary wastewater contains low value of organic matter and higher nitrogen content which may come from urine. The carbon to nitrogen ratio obtained from 50:50 and 25:75 was in agreement with the optimum C:N ratio. This is due to the smaller amount of organic matter in the sanitary wastewater which may be compensated by a high proportion of kitchen organic solid waste. The C:N ratio of 0:100 was beyond the optimum value, which shows kitchen organic solid waste is highly organic having relatively less nitrogen compared to sanitary wastewater. Therefore, it might need feedstock supplements that are rich in nitrogen such as sanitary wastewater, fecal sludge, urine etc.

Biogas production at different mixing ratios

The cumulative biogas produced during the experimental period for the different mixing ratio with time is shown in Fig. 2. The mixing ratio of 75:25 (kitchen organic solid waste: sanitary wastewater) produces 65.6 L of biogas and was the highest among the other mixing ratios used in this

Table 3 Characteristics of raw kitchen organic solid waste

Parameters	Unit	Present study	Literature
pH	–	5.3	5.5[a]
Total solid	% dry weight	18.7	16.14[a]
Moisture content	% dry weight	81.3	83.86[a]
Volatile solids	% dry weight	89.0	85–90[b]
Organic carbon	% dry weight	53.6	48–60[b]
Total nitrogen	% dry weight	1.82	0.1–2.9[b]

[a] Jayalakshmi et al. (2007)

[b] Jeanger (2005)

study. This may be due to the highly organic content of kitchen organic solid waste coupled with the supply of missing nutrients by sanitary wastewater that makes the C:N ratio within the desired range. This was followed by the mixing ratio of 50:50, then 100:0, then 25:75, and lastly 0:100. Biogas productions for the mixing ratios were 52.7, 50.0, 23.7, and 9.5 L, respectively.

Babel et al. (2009) conducted an experiment on anaerobic co-digestion of sewage and brewery sludge. They found that the maximum biogas production rate was for mixing ratio of 25:75 (sewage sludge: brewery sludge) and was 3.2 L/day. The result is also comparable with the findings of Amirhossein et al. (2004) which investigated that the production of the cumulative biogas was high when the organic component that easily biodegradable in the sample was higher. According to Amirhossein et al. (2004), the anaerobic digestion process for kitchen organic solid waste alone should give the highest amount of biogas due to the higher organic matter content, but it produced less biogas as compared to a mixture of sewage sludge and kitchen waste. This was due to the production of volatile fatty acid by the microorganism was more likely to be accumulated rather than to release biogas. The lower production of biogas might be due to from the unsuitable C:N ratio. Similar results were also obtained by Maria et al.(2008) maximum overall biogas yield was obtained by co-digestion of potato processing wastewater and pig slurry compared with individual potato wastewater or pig slurry digestion.

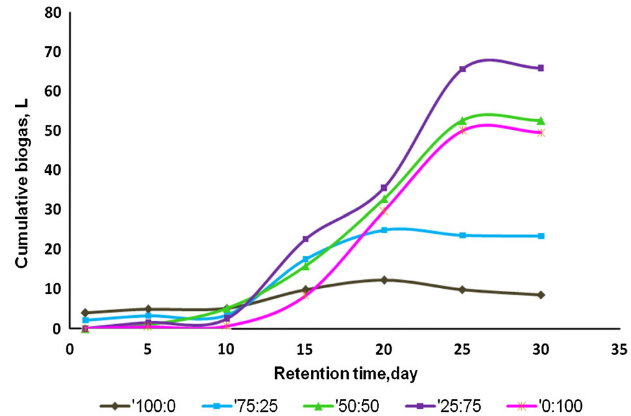

Fig. 2 Cumulative biogas production with time at different mixing ratios (sanitary wastewater to kitchen organic solid waste)

Considering the biogas production with the digestion time, the gas production rate of 100:0 was relatively rapid until the 10th day and then it increased slowly. The maximum production rate for this sample was observed during the 20th day. While the maximum biogas production for 25:75 was achieved at 25th day. On the other hand, biogas production rate of sample 0:100 was slower during the first 10 days and then it increased rapidly compared to other. The low biogas yield could be due to slower process of hydrolysis reaction in digestion and the accumulation of volatile fatty acids during this process. A retention time of 5 days during this process may not have permitted the full development of the slow-growing methanogenic bacteria. Similar results were also obtained by Azeem et al. (2011), during the initial acclimation phase, low biogas production, minimal or zero methane quantities, pH decrease, and volatile solid increase were observed for the digestion and co-digestion of pig slurry and abattoir wastewater.

Table 4 Characteristics of sanitary wastewater and kitchen organic solid waste mixture at different ratios

Parameters	Unit	Sanitary wastewater to kitchen organic solid waste				
		100:0	75:25	50:50	25:75	0:100
pH	–	6.15	6.9	7.1	7.3	7.2
TS	mg/L	7,068	14,395	25,328	48,789	56,084
VS	mg/L	4,241	9,357	20,265	42,324	49,915
COD	mg/L	15,099	42,128	59,871	95,344	135,863
BOD_5	mg/L	5,586	16,430	31,127	50,663	75,849
TOC	mg/L	2,356	4,950	11,258	23,513	27,730
TN	mg/L	220.4	448.6	513.2	849.4	894.7
TP	mg/L	203.1	364.7	381.8	419.5	578.2
TK	mg/L	120.2	179.3	212.5	235.7	276.6
C:N ratio	–	10.7	11.0	24.9	27.7	31.1

Methane percentage was also analyzed for all mixing ratios (Fig. 3). The highest methane percentage with an average of 52.8 % was obtained for 25:75, while 43.2 % for 50:50, 40.2 % for 0:100, 28.2 % for 75:25, and 19.8 % for 100:0 (sanitary wastewater to kitchen organic solid waste). The activity of methanogenic bacteria is higher for the mixing ratio of 25:75 due to the higher organic content and suitable C:N ratio. Wendland et al. (2006) investigated that, addition of kitchen refuse to black water (toilet water) improved the performance of the CSTR in terms of methane yield and COD removal efficiency.

To assess the efficiency of the process, the amount of methane gas was recalculated and expressed in terms of L/g $COD_{removed}$, and L/g $VS_{removed}$ (Fig. 4). The calculated volume of methane per gram of VS removed was always higher than that for the COD in all digestion feed stocks. Similar results were also obtained by Isaac (2003) in the case of fecal sludge; the calculated volume of methane per g of VS removed was always higher than that for the COD.

Removal efficiency of TS, VS, BOD_5, and COD at different mixing ratio after digestion

The characteristics of the effluent were analyzed when the digestion was completed and the removal efficiency was calculated (Fig. 5). TS of the effluent were reduced to about by 34.2–75.2 %. Reductions in VS were also ranged from 56.2 to 82.0 %. A higher total solid reduction was recorded by 0:100 (sanitary wastewater: kitchen organic solid waste). Considering volatile solids reduction, higher removal efficiency was achieved by 25:75. The higher removal efficiency of VS than the TS was a very good indication of high uptake rate of the organic fraction of total solids by methanogenic bacteria. From the percentage reduction of total solids and volatile solids, it can be concluded that co-digestion can reduce the amount and volume of kitchen organic solid waste which is disposed in dump sites. It can also reduce the cost of transportation as well as the task of the municipality's solid waste management sector. BOD_5 and COD reduction ranged from 59.1 to 79 % and 43.7–73.4 %, respectively. The COD removal efficiencies over the duration of the experiment are comparable to those reported in the literature ranging from 55–75 % for co-digestion process (Claudia 2008). The high removal efficiencies for COD are a good indication of the fact that the anaerobic co-digestion under proper operating conditions could be used for the treatment of sanitary wastewater and kitchen organic solid wastes before final disposal.

Characteristics of digested sludge compost and its suitability as a fertilizer

Among all mixing ratio, the digested sludge of 25:75 mixing ratio, which produces maximum amount of biogas

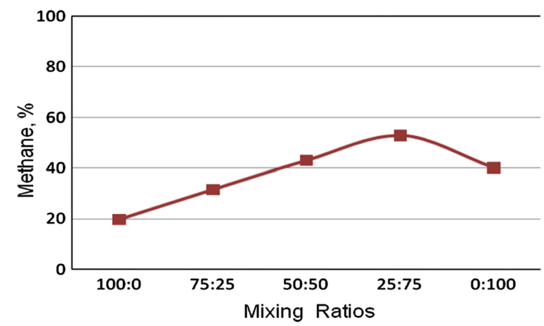

Fig. 3 Methane percentages with respect to different mix ratio

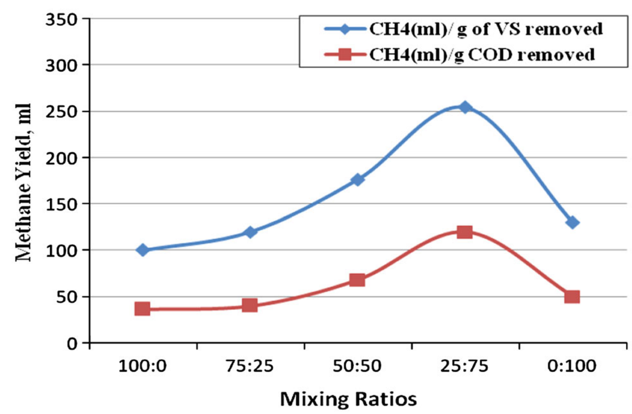

Fig. 4 Volume of methane produced per gram COD and VS removed in different mix

and methane was further treated using sun drying and composting process. The characteristics of the dried and composted digested sludge were determined (Table 5). The digested sludge compost shows near neutral pH values. The pH value met the compost quality standards used for agriculture in Switzerland (pH < 8.2), in Great Britain (7.5–8.5) (Shiferaw, 2009). The total nitrogen content was 2.7 %. It was also reported by Kuo et al. (2007) that for municipal solid waste compost to have fertilizing capabilities in agriculture, the total nitrogen content must be in the range of 1–3 %. The available phosphorous and available potassium found were 47.16 and 67.52 mg/Kg, respectively. The same result was also obtained by Kuo et al. (2007), the range of available phosphorous in typical compost was mostly between 40 and 110 mg/Kg dry weights and available potassium content of compost should be 60–120 mg/Kg. Hence, the digested sludge compost used from this experiment had enough content of macronutrients that can be applied for crop cultivation. The total volatile solid of digested sludge compost is 6 % of total solids. Heinonen-Tanski and van Wijk-Sibesma (2004) suggested that the organic matter of the digested sludge compost is important to improve the soil structure,

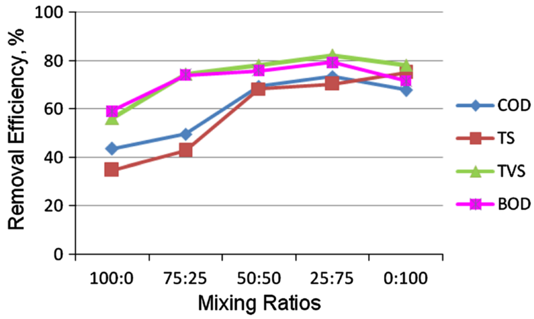

Fig. 5 Removal efficiency of TS, TVS, BOD_5, and COD after anaerobic digestion for all mixing ratios

making more resistance to droughts and erosions during heavy rains. According to Heinonen-Tanski and van Wijk-Sibesma (2004) increases in organic matter through the use of compost also make plants more salt tolerant.

A higher removal of total coliform and fecal coliform were also observed. This indicates that, the digested sludge compost can be used for agricultural purposes, which can support urban agriculture. The result is compatible with that reported by Ludwing (1988), in which complete removal of microorganisms and parasite observed when the fermented slurry was dried using direct sunlight. Charles (2007) conducted an experiment on composting of human excreta; fecal coliforms were killed because of elevated temperatures and by competition with the more resistant compost and/or soil microbes. Ellen (2004) reported the limit value by USEPA for fecal coliform concentration is <1,000 MPN/g of solid. The experimental results of digested sludge compost after sun drying for 3 weeks confirmed the complete removal of fecal coliforms.

Table 5 Characteristics of digested sludge compost of 25:75 (sanitary wastewater to kitchen organic solid waste) and comparison with standards

Parameter	Unit	Compost standard	Result from the study
pH	–	7.5–8.5	7.9
Total solid	% dry weight	–	94
Moisture content	% dry weight	–	6.0
Volatile solid	% TS	–	16.0
Total nitrogen	% dry weight	1–3 %	2.7
Total phosphorus	% dry weight	40–110	47.16
Total potassium	% dry weight	60–120	67.52
Total Cu	mg/Kg	0.2[a]	0.14
Total Ni	mg/Kg	0.2[a]	0.08
Total Pb	mg/Kg	5.0[a]	Trace
Total Zn	mg/Kg	2.0[a]	0.56
Total coliforms	MPN/g	–	9,600
Fecal coliforms	MPN/g	<1,000	897

[a] Metcalf and Eddy (2003)

The use of digested sludge compost as fertilizer has restricted applications based on heavy metal content, since these digested sludge may contain varied amounts of heavy metals that may be toxic for human and animal consumption. Such limitations were published in Metcalf and Eddy (2003). From the result, none of the heavy metals measured was over the maximum established limit values. Isaac (2003) indicated that the compost made from digested sludge should meet consumer and market requirements. Some of the criteria that ensure the marketability are: the compost must be largely free of impurities, it must not present any health hazards, the level of heavy metals, other toxic substances must comply with the standards, and it must have a visually attractive overall impression.

Conclusion

Condominium residences sanitary wastewater contains excess valuable nutrients that can be used for the production of methane. In addition, the expected metallic ions and heavy metals in this category of wastewater are within tolerable limits and, thus, can be used for biogas production. On the other hand, kitchen organic solid wastes are loaded by high organic portion with the most valuable elements; carbon for anaerobes that lead the co-digestion of the two wastes had become higher yield of biogas.

The findings of this study show that, maximum production of biogas with maximum percentage of methane is obtained in mixing ratio of 25:75 (sanitary wastewater: kitchen organic solid waste). Moreover, considerable average percentage removal of TS, VS, BOD_5, and COD was found for this mixing ratio. From the percentage reduction of those parameters, a reduction in the volume of kitchen organic solid wastes may be achieved if anaerobic digester is executed at the condominium houses.

A complete removal of pathogenic microorganisms in the digested sludge was observed after composting and drying process. In addition, the macronutrients content satisfied specific plant nutrient requirements. Moreover, heavy metals content was below the pollution control standard. Therefore, composting and drying process could be the best options for reducing the potential risk by completely inactivating the pathogen of digested sludge as a fertilizer.

Generally, the co-digestion of sanitary wastewater and kitchen organic solid wastes generated from condominium houses in mixing ratios 25:75 enhanced the quality and quantities of methane yield. Thus, the treatment option supports urban development by treating the organic waste at the source. The use of digested sludge compost could be the best alternative for the smallholder urban farmers for whom the high cost of inorganic fertilizers has remained a critical challenge.

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