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Effect of Mixing Ratio on Co-digestion of Septage with Sewage Sludge

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Abstract
Proper management of septage has been a challenge in Kathmandu valley.Co digestion of septage with sewage sludge in an anaerobic digester in an existing WWTP is an effective solution to this problem.This study was done to determine the optimum mixing ratio for addition of septage to the digester.For this, batch test was performed to determine the biochemical methane potential for the substrates i.e. sewage sludge and septage as well as for their mixtures.The result of biochemical methane test showed that the highest methane potential was found when 15% of septage by volume or 10% of septage by VS was added to sewage sludge.With respect to 5, 15, and 25% by volume of septage added, the measured methane potential was more than the projected methane potential by 9.06, 20.16, and 17.44%, respectively. This proved that adding septage into the sewage sludge has a positive synergistic effect on the digestion process.

Keywords
Anaerobic digestion, Co-digestion, Septage

1. Introduction

Rapid and unplanned urbanization of Kathmandu valley has put an enormous pressure on the water resources of the valley.With a total of 683,954 houses, the total population of Kathmandu has reached about 3.1 million [1].This has created a number of problems mainly in water supply and sanitation. In absence of proper sewage collection and wastewater treatment plants (WWTP), the river has become the main dumping site in the valley.

In order to achieve the global Sustainable Development Goals (SDG) target on water and sanitation, Nepal has also set its target as " more than 90 % house connection to water supply rate and more than 90 % of proper wastewater treatment rate by 2030". However the current baseline study has shown that Nepal is far from achieving its target.Even in Kathmandu valley, where the sewage system coverage is 70 %, there is lack of WWTP to treat the collected wastewater and most of the wastewater is directly discharged to the water bodies without proper or no treatment at all. Moreover, sewerage systems were laid in unplanned ways by the authorities, passing their problem to the downstream communities which ultimately led to the discharge of waste to the river system. Lack of proper awareness and policies to regulate the unregulated discharge has also added to the disposal of waste to rivers in Kathmandu valley.To address the problem of deteriorating condition of rivers in Kathmandu valley, the Government started the Bagmati Basin Water Management Strategy and Investment Program. However the program was proven unsuccessful as the pond system in Dhobighat, Kodku and Sallaghari were only partially operated.

Although the sewerage system is effective to treat sewage, it is very expensive and difficult to implement effectively especially for developing countries like Nepal. In Nepal most of the population depend on on-site sanitation such as pit latrine, septic tank, etc. 89% of Nepal practices on-site sanitation and 30% of the population in Kathmandu valley also uses one or other means of on-site sanitation practices.The waste from these sites are collected by private companies by vacuum trucks but are disposed of to the river without any treatment.The problem of fecal sludge management (FSM) is a pressing issue in Kathmandu valley. The government has recognized FSM as one of the key factors to improve the sanitation scenario and thus have included FSM for the first time in policy and target in 2020 [2].The government has set for 380 MLD of wastewater treated before disposal and 60000 m3/year fecal sludge to be managed by 2025.

Co-treatment with sewer based WWTPs is one of the possibilities for the treatment of septic tank waste.This option maximizes the utilization of infrastructures of the plant in cases where the existing treatment facilities are underutilized.Co-management of fecal sludge and septic waste with sludge produced during wastewater treatment would be a better option which includes anaerobic systems such as upflow anaerobic sludge blanket (UASB) reactors, anaerobic digesters and ponds.Anaerobic treatment can compensate for the cost of treatment through the production of biogas which can be used for heating or for the generation of electricity.

Although septage is anaerobically digested to some degree, several inhibitory factors such as uncontrolled temperature and pH, impurities, phase distribution by gravity, etc. causes incomplete digestion thus leading to leftover organic materials [3].This remaining organic matter in septage may help to solve the problem of low C/N ratio in sewage. Septage contains several nutrients from urine sources which can increase the organic and nutrient loading in the WWTPs.Also septage contains large amounts of trace elements such as Co, Ni, Cu and Fe which are essential nutrients for the growth of the microbial community in the digester[3].Thus it can help to increase the efficiency of anaerobic digester. Use of septage as a co-digestion substrate has some disadvantages.Depending upon the level of stabilization that the sludge has gone through septage may contain low concentration of biodegradable materials which will lead to low biogas production and high solid accumulation which will cause increase in operating cost thus limit the advantages of the co-digestion.It can lead to disruption of the co-digestion process by overloading of COD, ammonia inhibition, pH variation and sulphide inhibition which consequently causes inhibition of methanogens in the system [4].Therefore these factors are to be monitored and controlled to ensure proper operation of the treatment process

This study is aimed to determine the optimum mixing ratio for co digestion of sewage sludge and septage.To achieve this objective, methane potential test was performed for the sewage sludge and septage as well as their mixtures.The methane potential and biodegradability were evaluated and the synergistic effect of co digestion were determined for various mixing ratio.

2. Materials and methods

2.1 Preparation of sample

The substrates used for this experiment were, sewage sludge collected from Guheswori Wastewater Treatment Plant and septage collected from a septic tank located in Pulchowk Engineering Campus.The required inoculum for the experiment was also collected from anaerobic digester located at Guheswori WWTP.All quality parameters including pH, total solids (TS), volatile solids (VS), C: N ratio are to be analyzed according to the Standard Methods for the Examination of Water and Wastewater recommended by American Public Health Association (APHA) for the feed substrate and inoculum

2.2 Laboratory analysis

A brief test method for laboratory analysis has been shown in the table

Table 1: Brief description of laboratory test method adopted

S.N	Parameter	Test Method Adopted	Frequency
1	pH	pH meter	Daily
2	Total Nitrogen	APHA 4500N	
3	Total Solids	APHA 2540B	Before feeding and after HRT
4	Volatile Solids	APHA 2540E	
5	COD	APHA 5220C	

2.3 Experimental setup

The experimental setup includes a laboratory scale digester model in a 2-liter jar.The digestion was performed in a fixed ratio of VS based on production of SS and septage.The feed to inoculum ratio ≥ 2, is a ratio in which the digestion process does not show inhibition.The jars sealed with rubber stopper and stored in a chamber with temperature 37±1°C.The digesters were mixed manually once a day before the volume measurement was done.Biogas was measured using a liquid displacement method after passing the gas through a solution of sodium hydrooxide to assess methane content in the biogas.After methane production stopped, the digestate was finally sampled to determine TS, VS, pH, C/N ratio.Also a blank assay with inoculum only was used to correct the background methane production from the

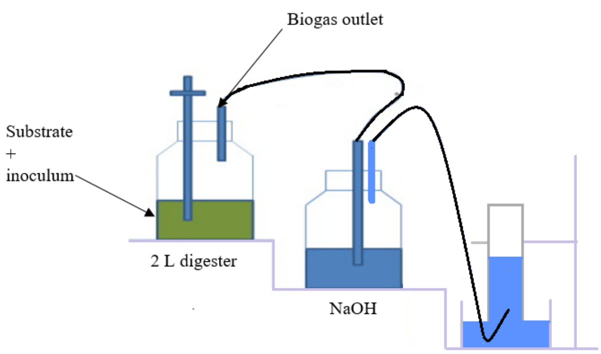

Figure 1: Systematic diagram of anaerobic digestion batch test

inoculum.The table 2 shows the digesters configurations performed during the tests

Table 2: Properties of digester

	Total volume (ml)	Head space (ml)	IN (ml)	PS (ml)	SS (ml)	Septage (ml)
Blank	2250	1350	900	-	-	-
PS	2250	1350	900	450	-	-
SS	2250	1350	900	-	450	-
SP	2250	1350	900	-	-	450
R1	2250	1350	900	214	214	22.5
R2	2250	1350	900	191	191	67.5
R3	2250	1350	900	169	169	113

2.4 Calculation

The theoretical methane yield for the substrates and their mixtures were calculated based on the stoichiometric formula.The theoretical methane yield of the mixture was calculated based on the proportions of SS and septage in the mixtures and actual methane production of SS and septage during the AD process, as shown in eqn below.[5]

$M_{mixture,i} = M_{ss,i} \times Y1\% + M_{septage,i} \times Y2\%$
where,
Mmixture,i = theoretical methane yield at the ith day of mixture (mL/g VSadded)
MSS i = methane yield of SS at the ith day (mL/g VSadded)
Y1% = the proportion of SS in mixture (%)
Mseptage,i = methane yield of septage at the ith day (mL/g VSadded)
Y2% = the proportion of septage in mixture (%)

The fed VS removal rate during the batch test was calculated based on total mass removal from the testing reactors and the blank reactors following the method. [5])

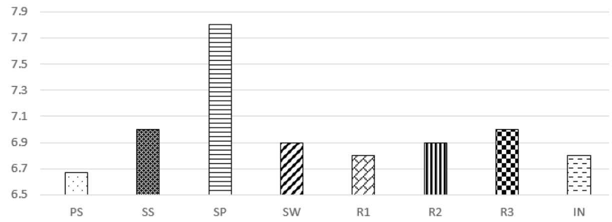

Figure 2: pH of substrates and their mixes

3. Results and Discussions

The properties of substrate and their mixtures are presented in the Table 2.

Table 3: Properties of substrates and their mixtures

S.N	Parameters	Unit	In	PS	SP	R1	R2	R3
1	PS	v/v	-	1	1	1	0.9	0.75
2	Septage	v/v	-	-	-	0.1	0.2	0.25
3	pH		6.8	6.67	7	6.8	6.9	7
3	TS	mg/L	45.6	97	1.6	49	49	42.8
4	VS	mg/L	17.8	63	0.9	15	16	15.5
5	VS/TS		0.39	0.6	0.6	0.3	0.3	0.36
6	C/N	-	3.7	6.4	0.2	3	1.9	2.71

3.1 pH

The Figure 2 shows the variation of pH along the substrates and their mixes.The result shows that the pH for PS, SS and Septage were found to be 6.67, 7 and 7.8 respectively.The higher value of pH for septage may be due to high ammonia content in the septage.Similarly the pH for the mixes were found to be in the range of 6.9-7. As the quantity of septage, having higher pH, increases in the mixture the pH of mixture also seems to be in the increasing trend.

3.2 C/N ratio

From the tests the C/N ratio for the PS, SS and septage were found to be in the 6.4 and 0.16 respectively.The low C/N ratio for septage may be attributed to low organic content and high nitrogen content in the septage.Due to the low C/N ratio of septage, the C/N ratio of the mixes were found to be in the range of 2.03-3.58.Also the C/N ratio of mixture of primary and secondary sludge (SW) was found to be 3.43.As the optimum C/N ratio for anaerobic digestion is in the range of 20:1 to 35:1, so

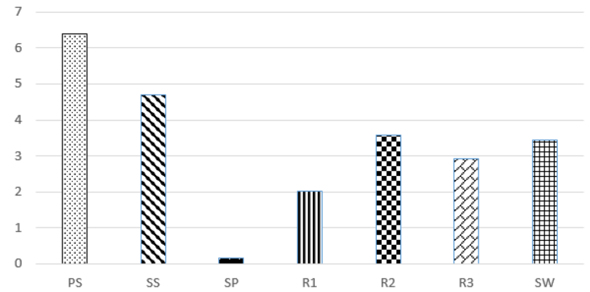

Figure 3: C/N ratio of substrates and their mixes.

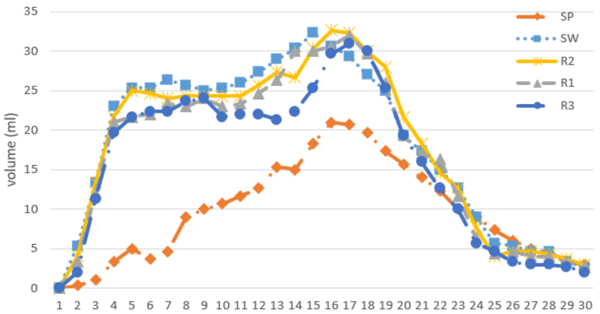

Figure 4: Daily methane production vs. time

saw dust is to be added to the digester feed before the digestion to make the C/N ratio in the optimum range.

3.3 Measurement of Methane Production

The methane produces was measured by liquid displacement method.The daily production of biogas and cumulative production of methane is shown in Figure 4 and Figure 5 respectively.

From the Figure 4, The digester which contains only septage, the volume of methane generated is low. This phenomenon can be due to high lipid content in septage. As the biodegradation rate of lipids is slower than that of carbohydrates and proteins, the digester shows minimum methane production. Among the mixes, R2 shows maximum methane production

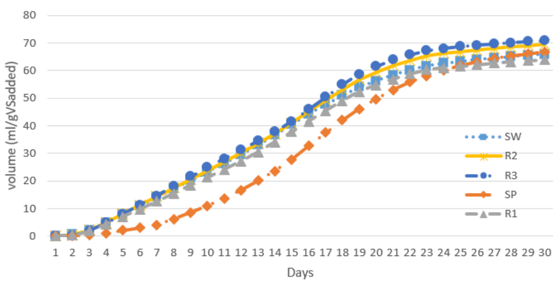

Figure 5: Cumulative methane potential vs. time

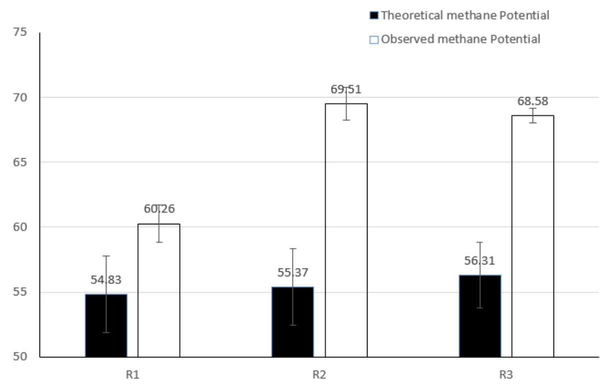

Figure 6: Comparison of observed and theoretical methane potential

followed by R1 and the least is for R3. The lower methane production for R3 is due to higher amount of addition of septage, i.e. 25% by volume. This causes increase in the amount of lipid content in the digester which inhibits the digester. Also the lower methane production of R1 can be explained by the lower pH of the digester. As the pH of the digester is low i.e. 6.8 compared to other mixes at the start of the digestion period, the chances that the pH will fall below the optimum range is of high possibility due to the production of volatile fatty acids during the acidogenesis phase. As the optimum pH for methanogenic bacteria is in the range of 6.8-7.5, the lower pH in R1 may be the cause of lower methane yield.

From Figure 5, it was found that the methane production potential for SW, SP, R1, R2 and R3 were found to be 65.2±2.25, 54.36±3.173, 60.263±1.44, 69.51±1.293 and 68.58±0.558 mL/gVSadded. This shows that the highest methane potential was found for R2 i.e. 15% of addition of septage by volume which corresponds to 10% of addition of septage by VS percentage. The higher potential of R2 can be explained by the fact that this mix contains highest C/N ratio among the mixes. Also there is decrease in methane potential when 25% (v/v) of septage is added. This may be due to excess amount of lipids in the system as septage is rich in lipids. This will decrease the amount of biodegradation in the digester resulting in low methane potential. And the low methane potential of R1 can be due to the function of its lower pH. Lower pH results in fall of pH below the desired level during the digestion period which will inhibit the production of methane gas.

Also from Figure 6, shows the comparison between the observed methane potential of the mixes with the theoretical methane potential calculated by weighted average of individual substrates according to their VS ratio. It was seen that the observed value was greater than the theoretical value for R1, R2 and R3 by 9.06, 20.16 and 17.44% respectively. This shows that there is synergistic effect of co-digestion of septage and sewage sludge. The synergistic effect of addition of septage can be explained by different factors such as supplement of trace elements and moistures and dilutions of toxic substances which can lead to better microbial activities. However as the amount of septage added increases, there are problems such as ammonia inhibition, pH variation, COD overloading, etc. which are likely to occur as it can cause inhibition to the production of methane. This can be the reason for lower synergistic effect when the 25% of septage by volume is added to the digester.

4. Conclusion and Recommendation

4.1 Conclusion

From the biochemical methane potential test, the methane potential of sewage sludge only, septage only, sewage sludge and septage in the ratio 95:5, 85:15 and 75:25 on the basis of volume were found to be 65.2±2.25, 54.36±3.173, 60.263±1.44, 69.51±1.293 and 68.58±0.558 mL/gVSadded respectively. The result showed that the highest methane production was found when 15% of septage by volume is added which corresponds to 10% of septage by VS. As the septage amount septage increases, the methane production decreases which may be due to excess amount of lipids added by septage to the system. Also lower volume of septage addition results in lower pH value which inhibits the methane production.b) The observed methane potential was greater than the theoretical methane potential by 9.06, 20.16 and 17.44% for 5, 15 and 25% of septage added respectively. This concludes that co-digestion of septage showed synergistic effect.d) Although all the mixes showed greater methane production potential, the maximum effect was observed when septage was added at 15% of septage by volume which is equivalent to 10% of addition of septage by VS percent. This shows that co-digestion of septage with sewage sludge is a possible option for proper management of septage in Kathmandu valley.

4.2 Recommendation

The recommendation for further study are: a) It is recommended to study the biogas generation for the mixtures in a plug flow model.
b) It is recommended to study the variation in pH, temperature and VS removal for the substrates and their mixes.
c) It is recommended to study the effect of C/N ratio on the biogas production..

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