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Excessive Scum Generation Consequences on Performance of Biogas Power Plant under Unregulated Alkanity

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ABSTRACT

Excessive scum formations adversely impacted on the economy, biology and functionality of the biogas plant. After the scumming events, the significant declination in overall performance of biogas plant was observed. In this research work, the critical experimentations were done on full scale biodigester from June 2017 to March 2019. The critical experimentations concluded the direct influence of the excessive scum formation on biogas generations, methane contents, pH of process and TSS contents. During the hot summer months, cold months of winters, rainy seasons and during the sudden change in a day temperatures the excessive scum formations occurred which hampered the overall performance of the biogas plant. The yield of biogas generation was reduced to 60% than normal biogas generations. The methane contents were only limited to 42%. pH was reported up to 6.1 only. Total solid contents were limited to only 1% which were expected to be 5 to 8%.

Key words : Biogas, pH, MSW, methane, scum

INTRODUCTION

Scum is amalgamation of slow degrading lignin, sewage solids, mainly gases, heavy oil and grease which floats on topmost part of digester in municipal biogas plants. The scum contained approximately about the 4% of total solid contents (Pan *et al.*, 2019). The scumming events cause the blockage in outlet pipes and operational problems in shredder and mixing units. Excessive scum leads to the higher maintenance costs and labour charges. It may result in shutdown of a biodigester for certain period. The scum adversely affects on microbial community which is responsible for methane formation by lowering the pH level. The microbes significantly depend on energy and carbon source which disturbs by lowering pH and hampers degradation as well (Jain *et al.*, 2015).

To control the scum formation some studies were done including the addition of ozone in aeration tank leading to the decomposition of floating scum and breaking mycolic acid which restricted the scum causing gordana and thus reduced the scum formations. Disinfection of gordana by the oxidizing property of ozone resulted in lowering the growth rate and inhibited its multiplication. These methods were applicable to septic tanks (Young *et al.*, 2013; Jiang *et al.*, 2018). No researchers claimed it for any MSW operated biogas plant. Some studies were conducted to study the effects of scum formations by loading little amount of scum (4 to 15%) to secondary biodigetser. The increase in scum formation (loadings) boosted the hydrolysis and acidogenesis stages of biogas production. The boosting of acidogenesis liberated more acids and lowered the pH of process and lowered the alkanity. The drops in pH of biodigester hampered the methanogenesis and led to lower the cumulative biogas productions. The necessary precautions must be taken to maintain the pH level to avoid the souring of the biodigester processes during the excessive formations (scum overloading). The scum loading resulted in increased long chain fatty acids (LCFA) contents which showed adverse effects on methane production (methanogenesis). The biogas generation from co-digestion of lower scum concentrations shows higher

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biogas formations and with higher scum concentrations biogas generations slightly decrease. The higher scum concentrations show more lag phase of eight days, while with lower scum concentrations show lag phase of only five days. The biogas production reported decrease with drop in pH level.

Concoction of the higher scum concentration and increased holding time lead to the adverse effect on digestion and lower the biogas yields. These research works did not reveal the scum formation effects on methane contents, degradation and TS contents. When pH was not monitored the digestion turns to be acidic and inhibits the methanogenesis process. The scum is co-digestible substrate under the optimal scum loading and neutral pH conditions. The excessive scum loading adversely increased the volatile fatty acid (VFA) concentration exceeding the digestible capacity of biodigester and imposing the difficulty VFA decomposition. The pH plays vital role in decomposition of VSS (Yuan *et al.*, 2018). When the smaller amount of the scum was co-digested the biogas production increased 50 and 100% under the different substrate mixture (Rodriguez-Roda *et al.*, 2018). The excessive scum loading enhances the slow to degrade lipids and long chain fatty acid contents of anaerobic biodigester. LCFA has lower solubility, may develop dead zones and may result in amalgations of insoluble particals.

Excessive scum loadings (formations) lead to hamper the methanogenesis by high partial pressure of hydrogen and high hydrogen level in liquid mixture. If the excessive formation continues it lowers the oxidation of the VFA that leads to increase in the acid concentrations (butyric and propionic acid) resulting in acidic digestion. The acitolactic acid formation leads to adverse effects on methanogenesis and biodigester fouling (Pan *et al.*, 2019). The previous research works did not reveal the scum formation effects on methane contents, degradation and TS contents.

MATERIALS AND METHODS

The substrate was collected from the various households, hotel and societies. The vegetarian food waste was accepted at the waste depot. The inorganic components like fibre, glass, polythene, non-veg and slow degrading waste were rejected. Every day, almost 5 t of waste was fed to biodigester.

Capacity of the K1 and K2 plants was 5 t each. Capacity of the digester was 80 cubic meters. Capacity of balloons used to store biogas was 80 cubic meters. Power generated by the generator powered by biogas was 40KW, which was used to light up almost 200 street lamps and in the premises of the plant. Special characteristics of the plant were that the water needed to form slurry was recycled i.e. only 10% of fresh water was used. Also the slurry was then recycled as manure for agricultural purposes.

The MSW collected from premises was separated on tray. The inorganic constituents like glass, plastic and slow degrading waste were completely removed and the mixture was crushed in shredder. The mixture was mixed with equal amount of water in 1:1 proportions (Fig. 1). The mixture was fed to primary digester. The mixture started decomposition and fed to secondary digester by gravity. The complete methanogenesis occurred in secondary digester and the biogas produced was passed to first hydrogen sulphide scrubbers to remove the H_2S and stored in two balloons of capacity 100 cubic meters. The biogas generation was measured by storing gas in balloons. The pH, TS and VSS were measured by APHA2005 methods. The methane contents were measured by method TCD on gas chromatography machine.

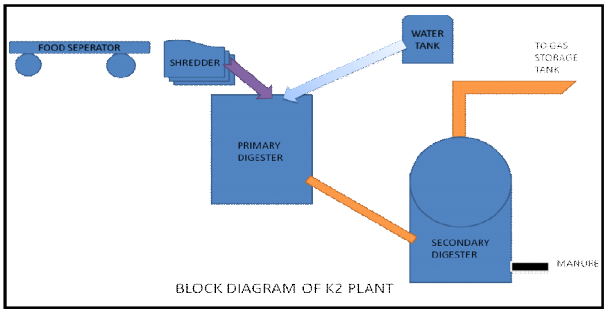

Fig. 1. Block diagram of K2 plant.

RESULTS AND DISCUSSION

The experimentations were performed on a full scale biodigester capacity (5 TPD) from June 2017 to March 2019 to evaluate the effects of scum formations on yield of biogas generations. The May and June 2017 were the retention time for the biodigester. The culture of methanogenesis microbes was developed

and only cowdung was fed as substrate to develop the culture of microbes. After the retention time of 30 days, the biogas plant was functional and biogas with good methane contents was produced. The cowdung was slowly replaced in parts with the municipal solid waste to change the substrate from cowdung to MSW. At the end of June 2017, the biogas plant was completely operational on municipal solid waste. The 5 t of municipal solid waste was fed per day to the plant for experimentations. The results of heavy experimentation are presented in Fig. 2.

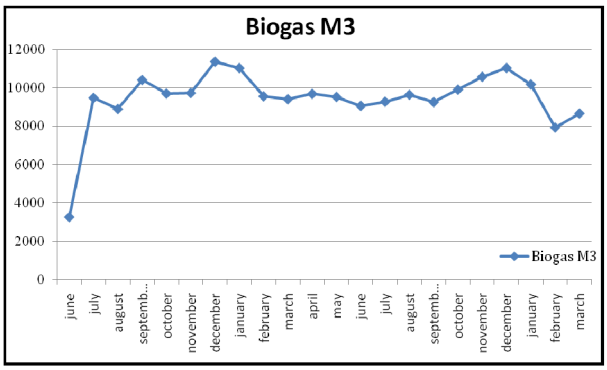

Fig. 2. Biogas generation from June 2017 to March 2019.

Fig. 2 clearly depicts the biogas generations on month basis from June 2017 to March 2019. The cumulative biogas generation was reported 9500 M^3 on month basis. The municipal solid waste processed by biogas plant was reported to be 150000 kg after removal of plastics, glass and other inorganic wastes. In December 2017 and 2018, cumulative biogas generations were reported highest around 11200 M^3 only due to ideal atomospheric conditions and no sudden changes in atmospheric conditions.

The yield of biogas generations was reported lowest in June 2017, February-March 2019 and August-June 2018. The biogas generations were lowest in June 2017 during the start of experiment due to installations, commisioning and initial retention time for microbes culture development. During February-March 2019, the scum formations were seen in primary digester. In some scumming events, the scum was omitted out of primary digetser which caused physical, biological and economical losses to biogas plant. The average biogas generations were lowest 8290 M^3 due to very high day temperatures of summer. The biogas generations were reported 60% than normal biogas generations. The microbes slowered the methanogenesis due to adaptions to climatic conditions. The scumming events were again observed during the August 2017 and June 2018. The cumulative biogas generation was reported 8570 M^3 due to rainy seasons with lowest temperature with biological adaptions. The excessive scum formations at the end of December 2017 and 2018 were reported due to declinations in biogas generations for consecutive next months. Similar drop in the performance was observed during scumming events of July and August 2017.

Fig. 3 plotted the final pH of the process from June 2017 to March 2019. The drops in pH indicated the reduction in the biogas generations due to acidic digestion inhibiting the methanogenesis. The drop in pH was observed after the excessive scum formations in primary digetsers in following periods. The ideal pH for the smooth methanogenesis was reported between 6.7 to 7.4.

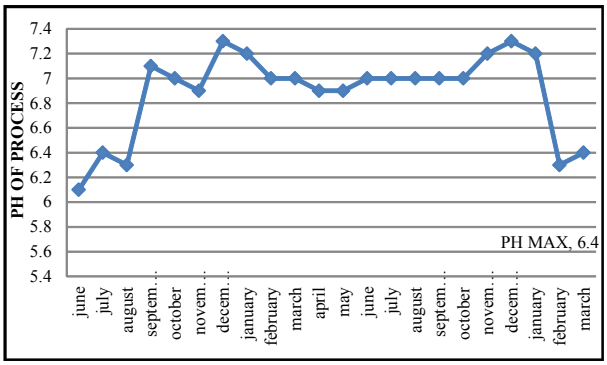

Fig. 3. pH variation during June 2017 to March 2019.

At the end of January 2019, the scum formations were seen in primary digester due to hot summer days. The pH of process dropped very much in month of February and March 2019 which was reported to be 6.1 and 6.2, respectively. The biogas generations were lowest 8290 M^3 due to sudden drop in pH during these summer days. The scumming events during July 2017 and June 2018 again led to pH droping upto to 6.2 to 6.5, respectively. The cumulative biogas generation was reported very less 8570 M^3 due to drop of pH due to rainy season. The microbes slowed the degradation of MSW due to adaption to the change in environmental conditions. The excessive scum formations at the end of December 2017 and 2018 resulted in drop in pH and reported declinations in biogas generations.

The methane contents were measured on gas chromotography machine from June 2017 to March 2019 (Fig. 4). The methane contents of generated biogas dropped drastically during excessive scum formations in primary digetsers and even stopped the formation of the burnable biogas.The methane contents in biogas were generally 50 to 68% in normal range. The heavy experimentations reported maximum methane contents of 65% and minimum 36% in generated biogas. The scum formations observed during the month of July 2017 and June 2018 indicated that the methane contents were only around 42% , pH dropped up to 6.2-6.5 and the cumulative biogas generation was reported very less 8570 M^3 due to sudden change in environment of rainy season phase. The highest methane contents were observed 65% in the month of December 2017 and 2018 under normal atmospheric conditions. The summer period January to March 2019 showed lean biogas formations with least methane contents. After the excessive scum formations, the digesters turned acidic and the digestion process suffered very much. The inefficient methanogenesis occurred resulting in poor digestion process and least methane contents.

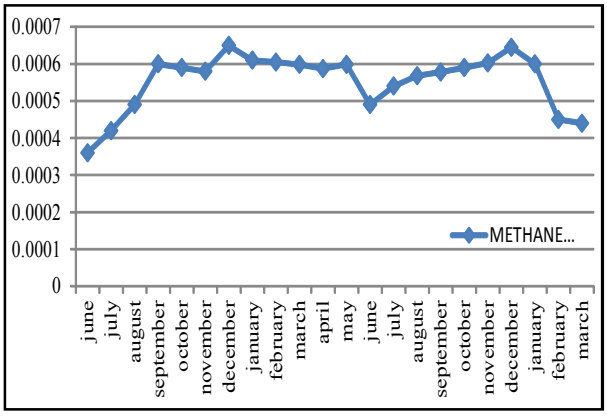

Fig. 4. Methane contents of biogas measured from June 2017 to March 2019.

Total solid (TS) of primary digester was less than 1%. It was expected to be 5-8%. Scum had mostly TSS and VSS contents. During the scumming events, the scum overflew from the mouth of primary digester and vital contents in TSS and VSS lost drastically which was potential loss of substrate in the biodigester. Scum overflow reduced the soluble COD and VFA generations with and without pH monitoring.

CONCLUSION

The excessive scum formation showed negative impact on methanogenesis of the biogas plant. The excessive formation hampered the economy of the biogas generations and lowered the methanogenesis.

1. In June 2017, February-March 2019 and August-June 2018, the yield of biogas generations was reported lowest, pH of process dropped very much in month of February and March of 2019 which was reported as 6.1 and 6.2, respectively, with acidic digestions along with the least methane contents around 42%.
2. The scumming events were observed again during August 2017 and June 2018, the cumulative biogas generation was reported 8570 M^3 due to rainy seasons, lowest temperature with biological adaptions, which led to pH drop up to 6.2 to 6.5, respectively. The microbes slowed the degradation of MSW due to struggling the adaption to the change in environmental conditions with least methane contents.
3. After the excessive scumming events, the TSS, VSS, COD and VFA reduced drastically. Total solid (TS) of primary digester was less than 1%. It was expected to be 5-8%.
4. In December 2017 and 2018, cumulative biogas generations were reported very high around 11200 M^3 only due to ideal atomospheric conditions and no sudden changes in atomospheric conditions.

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