Setup Design for the Production of Methane Gas from Kitchen Waste

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Abstract. Generation of kitchen waste is increasing day by day because of raise in population as well as change in socio-cultural habits. Most of these wastes can be decomposed by the action of microorganisms in a short span of time because they are biodegradable substances. E.g. Food waste, vegetable peals, fruit pulp etc. If these materials are dumped in soil or kept in open, it undergoes microbial changes & releases Carbon dioxide, Methane, Ammonia & Hydrogen sulphide which can lead to air pollution and foul smell. If these gasses are trapped properly, it can be used as a source of energy and can save environment on the same go. In the present paper, work has been done on a setup for conversion of kitchen waste into energy which will be useful for college canteen & mess, and at places where a large amount of waste are generated on daily basis. The setup design for the production of methane gas has been done using Solidworks software (2016 version) and stress analysis of the methane gas collector has also been carried out. This setup also consists of flow measuring sensors which can measure the amount of gas formed & used, in a certain period of time. This setup will be connected via mobile app for real-time data and can be used anytime for monitoring of gases and for research purpose as well.

Keywords: Kitchen Waste, Bio gas, Anaerobic Digester, Manure

1. INTRODUCTION

In today’s world, with growing population the demand of energy is increasing rapidly [1]. To meet this demand, there is a need to see beyond non-renewable source of energy load since it is rapidly declining and also it generates pollution during combustion. To overcome this problem there are many renewable energy sources like wind energy, solar energy, hydro power energy, biogas energy etc. [2]. But it was found that biogas is totally different from all other energy sources because in this there is a provision for collection & control of organic wastes and the by product can be used to create fertilizer & water for irrigation [3]. Biogas has certain more advantages like it is not bounded by geographic limitations and no advanced technical setup is required. The input in this model, for generation of methane gas, kitchen waste can be considered because it has high calorific value and high nutritive value for microbes which ensures high efficiency [4]. Use of kitchen waste is also beneficial as in many cities these kitchen wastes are either dumped in open or disposed in landfills. If kitchen waste is abandoned in open, it can lead to various diseases like malaria, cholera, typhoid & if decomposed in landfills, it can pollute surface as well as groundwater too by leachate and contributes to breeding of...
mosquitos & flies. This decomposition also releases stinking smell of methane gas which not only pollute environment but also production of methane adds up in greenhouse gas [4].

2. BIOGAS

Bio gases are created when degradation takes place by action of bacteria on organic material anaerobically, meaning when organic matter break down anaerobically it releases a blend of gasses which includes methane & carbon dioxide [5]. This system also produces residue of organic waste which is high in nutrition (when compared with other organic fertilizers) and further can be used as manure. Biogas system also acts as a decomposition system for human, animal as well as for agricultural wastes to prevent environment contamination & spread of pathogens along with other disease causing bacteria. It has numerous advantages like eco-friendly disposal, aiding in global warming reduction and many more some of which has been listed below [6]:

- It can produce energy from waste material.
- It can reduce air pollution.
- It is helpful in making revenue from waste material.
- Production of good quality fertilizers.
- Reduce number of pathogens.
- Enhances quality of air, soil, water, etc.
- Economic benefits.

| Parameters     | Results                                      |
|----------------|----------------------------------------------|
| Weight         | 20 % Lighter than air                        |
| Temperature Range | 650 °C to 750 °C.                          |
| Calorific Value | 20 Mega Joule(MJ)/m³                      |
| Efficiency     | 60% (Approx.)                                |
| Usability      | Replacement of wood, petrol, diesel, LPG, Coal etc. |

3. LITERATURE REVIEW

3.1 Shalini Singh [2001][7]- Shaliniet al. studied on bacteria effect on biogas production in 2001 in which she studied the effect of aquasan&terasan microbes on biogas production from kitchen waste and came to results that addition of aquasan on day 1 & day 15 on cattle dung increases the production by 55%. If addition takes place on mixture of kitchen waste & cow dung [1:1] leads to 15 % more gas production.

3.2 Peter Wieland [2010][8]- Peter Wieland in 2010reviewed different perspectives of biogasproduction like biochemical or feedstock which can affect gas production.

3.3 Jong Won Kang (2010)[9]- Jong et. al. (2010)researched on the way of removal of H2S from biogas prepared from kitchen waste and came to a conclusion that bio filter is best for adaption for steam reforming process.

3.4 Sudha.G. (2012)[10]- Sudha.G. in 2012 worked on Production of biogas from different fruit pulp and came to a conclusion that more amount of chemical oxygen demand (COD) leads to more production of biogas.

3.5 LetaDeressa (2015) [11]- Letaet. al. in 2015 studied the production of bio gas from fruit, vegetable & cow dung mixture in anaerobic digester.

3.6 AnandKarve (2004) [12]- Anandet. al. in 2004 developed a bio gas system in which he used starchy & sugary feedstock and came to a conclusion that this system is 800 times more efficient.
After reviewing few papers above, we found that there is some research gap in earlier works which includes:

- Lack of setup for measurement of gas produced & used.
- Costly Setup.
- Low Productivity.
- Lack of Re-usability of sludge.

4. EXPERIMENTAL SETUP AND PROCEDURE

Figure 1 consists of a slurry input port from where kitchen waste & water mixture is added to the system. The non-return valve just ahead of the slurry tank prevents any back flow. The slurry then goes into digester where it reacts with microorganism anaerobically and produces gasses like CO2, CH4, and NH3. Since gasses are lighter than slurry waste (the slurry is basically a mixture of solid & water), moves upward and can be collected in methane gas collection tank by passing through the non-return valve fitted ahead of methane gas collection tank. While going to this storage tank it has to pass via a flow measuring sensor which will measure the amount of methane formed & used, in a certain period of time. This sensor can be connected via mobile app for real-time data and can be used anytime for monitoring of gases formed and used. The data so collected can also be useful for research purpose. Thereafter, rich nitrogen residue of digester is collected in sludge collection tank which passes through the non-return valve. This byproduct can be later on taken out by opening silt and can be used further as manure in fields. This manure is much better than other organic fertilizers available because of rich content of nitrogen. In this setup the material used for fabrication is hard plastic or iron and for the methane gas collection it can be AISI 304. Dimensions of digester depend upon quantity of waste produced per day. Cow dung is added 10% initially to inject anaerobic bacteria in the digester which will reduce further to 5% [5]. In addition, non-return valve is added to ensure unidirectional flow of sludge material and gasses.

In comparison with earlier worked papers we found some uniqueness in our work which includes:

- Flow measuring sensor.
- Real time data monitoring.
- Opening for sludge collection.
- Use of sludge as manure.
- Low cost Setup.

![Fig. 1 Anaerobic digester model with flow measuring sensors](image-url)
5. DEVELOPED DESIGN OF DIGESTER MODEL

Biogas digester Design Parameters includes C/N ratio of 20 to 30, Hydraulic retention time of 1 to 30 days, PH of 6.5 to 8, Temperature of 15 to 45°C, mixing ratio of 10 to 20 %w/v [13]. The following figure shows the components and assembled 3D model of the digester developed using Solidworks software (version 2016). All dimensions are in inches. The Waste gets collected in the Slurry collector, the design of which has been shown in figure 2. It then flows down through the pipe as shown in figure 3. Slurry settles down in Digester chamber, design of which has been shown in figure 4 where decomposition takes place. The waste gets collected in sludge collection chamber, shape of which has been revealed in figure 5. Figure 6 shows the gas flow measuring sensor which has to be mounted on top of the digester chamber. Figure 7 shows the design of Non return valve which has to be installed at different section of pipe as discussed in schematic diagram as in figure 1 for unidirectional flow. Figure 8 shows the dimensions of methane gas collector chamber. Finally figure 9 shows the assembly of all the components.
6. RESULT & DISCUSSION
The problems faced while designing the biogas plant includes monitoring of temperature, gas leakage check, resizing of wastes etc. These problems can be sorted out by using the proposed design as discussed above. The expected production of methane gas from 1:1.5 waste to water ratio using this model is around 2.5 m³[14]. The static stress and strain analysis for the methane gas collection chamber has been done in order to check feasibility of the proposed design, since methane is the main product of this study and it’s storage is prime concern. Proposed material for the gas chamber is AISI 304[15]. The pressure has been assumed to be around 500Psi. The maximum Von Misses stress that may occur as per analysis is $4.36419e+008$ N/m² as shown in the figure [10] and the maximum strain is 0.00143352 as shown in the figure[11]. Also the figure [10], [11] does not show any red region in the analysis which means that the proposed design is safe for fabrication. Hence stress and strain analysis ensures that the methane gas produced through this setup can be stored safely in the gas chamber up to a pressure of 500Psi.

7. CONCLUSION
On the basis of above study, we can conclude that a biogas digester is simple in operation and are much effective in saving environment as well as economically beneficial. Bio gas is a renewable
energy source and can be used for cooking in kitchen, rotating turbine at power stations, and can be
used as fuel to run vehicles also. The gas produced here can be used as an alternative to the fuel and
can also be sold to the neighbors. The gas collection chamber (proposed to be of AISI 304) has been
designed to bear pressure up to 500Psi this is quite evident from the analysis carried as shown in figure
10 and figure 11, which is way better than pressure in the pipeline carrying natural gas (400Psi). The
static analysis reveals that it is quite safe for the storage of methane gas since the stress and strain
generated are well with the maximum stress of 4.36419e+008 N/m^2 and strain of 0.00143352, also
the analysis does not show any red region. The by-product of this setup can be used as manure as it is
rich in nitrogen. It can also be used for reducing gap between energy demand and supply by extracting
bio energy from kitchen waste. Further after evaluating some papers, observation has been that it may
be costly during installation but can give much high return in long run. It was also found that it is hard
to monitor the volume of methane gas produced. In this paper, discussion has been done wherein a
flow measuring sensor has been used which can be connected with mobile via IOT. So, developed
model has the ability to monitor real-time production and flow of methane gas. This feature can be
used for monitoring as well as in research work.

8. FUTURE SCOPE
There are various future research scopes in this field which includes selection of material of
digester, installation techniques, and maintenance methods for biogas plant. There is also scope for
research in enhancing the waste circulating system for better decomposition of kitchen wastes. The
system can also be upgraded to automatic instead of manual feeding.

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