DESIGN AND PLANNING OF AN ANAEROBIC DIGESTER FOR ORGANIC FRACTION OF MARKET WASTE OF GWALIOR

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Abstract* — Since the early days of solid waste management practices, the negative impact on the environment is very visible in Gwalior city. In this situation, there is an urgent need for a processing and energy recovery facility for biodegradable waste which includes market waste (fruit peeling, vegetable waste & temples leftover). Market waste is being ignored due to bulky waste generation. Even after there is no separate collection of market waste ultimately they get mixed with Municipal solid waste. It is particularly necessary for the municipal solid waste (MSW) management sector, which has been neglected for many years. In this context research has been carried out to contribute to the development of efficient structure which approaches for treatment of food waste in Gwalior city. This study is an attempt to explore current situation in municipal waste management sector particularly for food waste, and to design a waste to energy technology by selecting a suitable anaerobic digester.

***Keywords*— Anaerobic digester, fruit, vegetable & temples leftover waste, Food waste, Gwalior city, Anaerobic condition, Biomethanation.**

I. INTRODUCTION

Solid waste is basically unwanted or discarded material that is not a liquid or a gas. Waste is generated by activities in all economic sectors and considered as an unavoidable by-product or material leftovers from various activities. The impact of waste through generation and accumulation on the environment and human health is significant such as:

(i) Aesthetic aspect
(ii) Water and soil contamination
(iii) Land degradation
(iv) Habitat deterioration

Also, the generation of waste reflects a loss of materials and energy and imposes economic and social costs on society for its management

ANAEROBIC DIGESTION: It is also referred to as biomethanisation, is a natural process that takes place in absence of air (oxygen). It involves biochemical decomposition of complex organic material by various biochemical processes with release of energy rich biogas and production of nutritious effluents. The three important biological process (microbiology) are,

- Hydrolysis: Breakdown of complex insoluble organic matter into simple sugars fatty acids and amino acids.
- Acidogenesis: Further breakdown of simple sugars, fatty acids & amino acids into alcohols & volatile fatty acids (VFAs).
- Acetogenesis: Conversion of VFAs and alcohols into acetic acid, CO2 and hydrogen.
- Methanogenesis: Finally the acetic acid and hydrogen is converted into methane and carbon dioxide by methanogenic bacteria.

The AD process is applied to process organic biodegradable matter in airproof reactor tanks, commonly named digesters, to produce biogas. Various groups of microorganisms are involved in the anaerobic degradation process which generates two main products: energy-rich biogas and a nutritious digestate which can be used as soil conditioner.

It transforms organic waste material into valuable resources while at the same time reducing solid waste volumes and thus waste disposal costs. One of the end product of anaerobic decay is biogas, which is produced naturally from decay under water. Biogas is a methane rich gas that is produced from the anaerobic digestion of organic material in biological-engineered-structure called the digester.
This technological process is necessary here to save the valuable sources. Since solid waste management of fruit & vegetable markets is not satisfactory. And this inefficient management lead to the loss of valuable resources whereas this market waste and temple floral waste has a high potential for the generation of biogas subjected to anaerobic digestion.
This study includes the design procedure and an investigation of the properties of the refuse, with a view to establishing appropriate principles and consideration for the design of digester. And also the aim of the study to prevent mixing of market and temple floral waste with municipal solid waste as far to reduce the loading of landfill and providing a separate technological process to deal with the market refuse.

II. STUDY AREA

Gwalior is a city in the central Indian state of Madhya Pradesh. It's known for its palaces and temples. **Gwalior** is a major and the northern-most city in the Indian state of Madhya Pradesh and one of the Counter-magnet cities. Located 319 kilometres (198 mi) south

of Delhi, the capital city of India, Gwalior occupies a strategic location in the Gird region of India. Gwalior is surrounded by industrial and commercial zones of neighbouring districts (Malanpur – Bhind, Banmor – Morena) on all three main directions. Hinduism is a religion which is practiced by the majority of the people in Gwalior (88.84%). In Hinduism people offers water, fruit and flower to God. Gwalior city is located at (Latitude: 26° 13' 25 N, Longitude: 78° 10' 45 E) on Indo-Gangetic plains in the state of Madhya Pradesh. As per the data provided by ICLEI in 2015, the city has a population of about 11, 59,032 (as per census in 2011, the population was 1069276). Gwalior Municipal Corporation (GMC) is responsible for the management of the MSW generated in the city. The city is divided into 66 municipal wards (including newly added 6 wards). The city area around 423.35 km^2. Here market areas of 9 wards are selected for analysis purpose.
Locations which include these 9 wards are listed below:

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Locations which include these 9 wards are listed below:

Table 1: Area in the ward and their ward number for study

Ward No.	Area Name
02	Morar Vegetable Market
05	Motijheel Fruit Market
10	GhasMandi
12	Hazira Vegetable Market
32	Padav Hanuman Temple, Saibaba Temple, Khedapati Temple, Koteshwar Temple
37	Laxmiganj Veg. Market, Gupteshwar Temple
40	Fruit Market,Veg. Market, 4 Big Temples
45	Achleshwar Temple
46	MaharajBada Temple, Mosque

Gwalior has a sub-tropical climate with hot summers from late March to early July, the humid monsoon season from late June to early October, and a cool dry winter from early November to late February. The highest recorded temperature was 48 °C and the lowest was −1 °C.
The study area consisting of those wards where market waste and the major temple's of Gwalior city are mainly generated a large proportion of organic fraction of Municipal solid waste for which there is no data or record on paper.
There are 09 wards which include all fruit & vegetable markets and temples where people offers water, fruit and flowers to God.
All the waste generated through those places mixed with Municipal solid waste as there is no separate provision of collection of these wastes. Though twin bin system vehicle goes there to collect daily market waste but ultimately they disposed into a dumping site at Barah near transport nagar and at kedarpur, shivpuri link road Gwalior. Where all the waste inorganic and organic mixed and there is no Recovery or Recycling of waste is practicing.

III. NEED OF THE STUDY

In Gwalior city there are whole sale markets of fruits and vegetables where huge masses of waste are generated. And being an Indian city there are 88.84% people are Hindu who believe in worshiping of God by offering them water, fruits and flowers in temples so quintal of waste generated in Hindu temples which require a proper segregation and collection system for that. Since the waste is biodegradable in nature so it cannot be ignored or disposed as a discarded material. This market and temple waste has the potential to recover energy which can be utilized to generate electricity or can be used as gas for households or any other purpose by Selecting a suitable technologies for anaerobic digestion process to utilize this biodegradable waste.

Following features can be achieved by utilizing biodegradable or food waste.

- ✓ Treats food waste sustainably
- ✓ Can improve management of the waste.
- ✓ Can reduce reliance on landfill
- ✓ Can use methane gas for house hold use.
- ✓ Produces a renewable source of energy

- ✓ Can help in reducing greenhouse gas emissions
- ✓ Can help save money on energy bills

IV. OBJECTIVE OF THE STUDY

- To study current situation of solid waste management particularly for market waste (vegetable and fruit waste) and temple floral waste and find characteristics of the sample collected from selected wards for our study.
- To design a waste to energy technology by selecting a suitable anaerobic digester.

V. METHODOLOGY

A. *Site visiting:*

First site has been visited as there are 4 vegetable market, 2 fruit market and 12 big temples. Large quantity of waste is generated in these areas. We took a look of dumping yards; the waste there is spread, not collected systematically. In this study, characterizations of market and Temples waste are carried out by visiting different wards. By selecting sampling sites for information collection and visiting various places like container sites, dumping stations. On the basis of observing problem & discussion with vendors, it is suggested for improvement in transportation & disposal of solid waste.

B. *Information collection* :

The information is collected about the place and no. of container, No. of shops or vendors, Category of shops, generation of food and flower waste, quantity of waste & its characteristics. In markets huge amount of food waste is generated which require any processing technology by which we can restore end product.

C. *Sampling & Testing*:

Samples were collected with waste Quartering & coining Sampling Procedure. Sample is then analysed and various parameter of physical and chemical characteristics were evaluated. Parameters like pH, Moisture Content, protein, Total Nitrogen content, carbon content, Volatile & Non Volatile Content, C/N ratio is carried out by using Indian Standard codes.

D. Following Indian Standard codes are used to determine characteristics.

IS 9234 – 1979, this standard prescribes a method for preparation of samples of solid wastes for chemical and microbiological analysis. There are three basic operations required to prepare the sample for detailed analysis are as follows:

- drying,
- grinding or pulverizing,
- And mixing.

The end products of these operations is thoroughly homogenized that portions weighing 100 to 200 mg is extracted for analysis.

IS 9235–9179, this standard prescribes a method for physical analysis and determination of moisture in solid wastes excluding industrial wastes. Crude refuse 1 to 2 kg may be taken as the basic unit for a sample. The moisture content of the crude sample is determined during drying. It is essential that this moisture content of sample is measured as so as possible after the sample is collected.

IS 10158–1982, this standard prescribes methods of analysis of solid wastes (excluding industrial solid wastes) for the determination of the following.

a) Volatile and non-volatile matter,
b) Total nitrogen content
c) pH
d) Carbon content

IS 9569–1980, this code used for the Glossary and terms relating to solid wastes.

E. *Selection of Anaerobic digester*:

The choice of the basic Anaerobic digester design is influenced by the technical suitability (includes moisture content, temperature, solid content), i.e. it should be capable of flow so can be used in continuous operation and convenient to access into inlet. It also depends on the climatic, economic conditions, cost-effectiveness, nature of waste and the availability of local skills and materials. For small scale treatment, the fixed dome type anaerobic digester is considered as it can be constructed underground and low cost of construction. This fixed dome type is suitable for total solids content of greater than 10% or for wet anaerobic digestion process. Generally the hydraulic retention time is 20-30 days depending on the kind of feed and operating temperature. So in this analysis the designing of fixed dome type digester will be discussed and its biogas and nutrient rich digestive production.

VI. RESULTS AND DISCUSSION

Physio- chemical analysis:

The methods of Indian standard codes i.e. 10158- 1982 is used to perform various physical and chemical analyses. The results of the same are as follows:

Table 2: Parameters of Organic fraction of Market waste and temples' leftover:

Sr. No.	Parameters	Results	Standard range
1.	Moisture content	45 %	45-55
2.	pH	7.2	6.5-7.5
3.	Carbon content	29.08 %	-
4.	Volatile content	80 %	80-85%
5.	Protein	8.5525 %	-
6.	C/N ratio	21.22 %	16-25
7.	Nitrogen (N_2)	1.3%	-

The optimum pH for a generally stable Anaerobic Digestion process is in the range of 6.5-7.5. During digestion, the processes of hydrolysis and acidogenesis occur at acidic pH levels (pH 5.5-6.5) as compared to the methanogenic phase (pH 6.5-8.2). And optimal C/N ratio is in the range is in between 16-25. A high C: N ratio is an indication of rapid consumption of nitrogen by methanogens, which then results in lower gas production. On the other hand, a low C:N ratio causes ammonia accumulation and pH values then may exceed 8.5. Such conditions can be toxic to methanogenic bacteria. So the parameters of the study are in the range of optimal limits.
Anaerobic Digester System: Fixed dome type digester was selected since it has relatively low construction costs, long life span if well-constructed, absence of moving parts or corroding metal arts, Underground construction saves space and protects the digester from temperature fluctuations. In fixed dome type there is no rusting steel parts hence a long life span can be expected. No day/night fluctuations of temperature in the digester positively influence the bacteriological processes. Hence fixed dome type digester is good enough as anaerobic digester though it requires some parts of waste to make it in slurry form.
And this type of digester is best suited for smaller quantities of waste.

DESIGN OF FIXED DOME TYPE ANAEROBIC DIGESTION SYSTEM:

Daily waste generated according to data collected is 1 tonne (wet weight) per day from the areas which are selected for the study. And by taking marginalized vendors or market's growth, the waste generation is considered as on an average 1.5 tonne. i.e. 1500 kg (wet weight) including food and floral waste
This raw feedstock will be diluted with water in a ratio of 1 part waste to 0.5 part water forming slurry which is capable to flow.

Daily feedstock to the digester = 2250 L (i.e. 1* 1500+ 0.5 * 1500), using the approximation that 1 kg is equivalent to 1 litre).
Hydraulic Retention Time (HRT)
The ideal HRT for a tropical climate with an average ambient temperature of 25 – 30 °C is recommended to be around 30 days, which means that an active reactor volume of 68 m^3 is required (i.e. 2250 L /day * 30 days = 68000 L or 68 m^3).
Feedstock characteristics and Organic Loading Rate (OLR)

The available biowaste (mix of vegetable, fruit and food waste) has a Total Solids (TS) content of 20 %.
Total solids (20%) = 300kg of 1500 kg wet weight (dry matter)
The Volatile Solids (VS) content of the dry matter is 80 %,
Volatile Solids (80%) = 240kg of 300kg dry matter
Non-Volatile solids = 60kg.

The balance of the biowaste is water which does not contain Volatile Solids
the share of Volatile Solids = 240 kg of 2250 kg diluted feedstock daily.
Diluted feedstock Inflow = 240* 1000/2250 = 106.66 kg VS /m3. (1000 lit = 1 m^3)
The Organic Loading Rate (OLR)
Organic Loading Rate = Q * S / V
Where, Q = substrate flow rate (m^3/day),
S = substrate concentration in the inflow (kg VS /m^3)
And V = reactor volume.

Therefore:
Organic loading rate = 2.25 (m^3/day) * 106.66 (kg VS /m3) / 68 (m^3) = 3.529kg VS per m^3 reactor volume and day.
An OLR below 2 kg VS /m^3 reactor volume and day is considered ideal for non-stirred AD systems

Size of the anaerobic digestion system:
A fixed-dome digester (e.g. Nepali GGC2047 model) is designed so that 75 % of the total reactor volume is used for the active slurry and 25 % of the volume is used for gas storage.
Since, the active volume of 68 m^3 (equals 75 % of total) is complemented with 22 m^3 gas storage volume (25 %),
Thus total digester volume = 90 m^3 for the whole reactor.
Biogas volumes that a food waste typically yield = 0.67 m^3/ kg VS
Assuming 0.4 m^3 CH_4 / kg VS i.e. 60 % methane and 0.26 m^3/ kg VS i.e. Carbon-dioxide.

Biogas flow rate (Q)

3.529 kg VS /m3 reactor and day * 0.67 m^3 biogas yield per kg VS * 68 m^3 reactor volume,
Total biogas yield = 160.78 m^3

Assuming that the biogas consists of 60 % methane (CH4) and 40 % carbon-dioxide,
Total methane yield of 102.23 m^3.
The Gas Production Rate (GPR):
GPR = Q (biogas) / V (Reactor volume)
GPR = 160.78 m^3/ d / 68 m^3 = 2.364 m^3 biogas /m^3 reactor and day.

The Specific Gas Production (SGP):
SGP = GRP / OLR
Therefore: SGP = (2.364 m^3 biogas / m^3 reactor and day) / (3.529 kg substrate / m^3 reactor and day) = 0.66 m^3 biogas / kg VS fed material.
And hence 159 L / 30 days of specific biogas production we can have.

VII. CONCLUSION

The present study was an attempt to find out the current situation of market waste (fruit and vegetable) and temple floral waste management of Gwalior city. As per the information gathered about 1500kg waste is generated from the wards which we have taken for study. And the parameters were analysed to select a suitable anaerobic digester. A fixed dome type digester was taken to treat biodegradable market waste as it is suitable for total solids content of greater than 10%. And by this technique we can have 159L of biogas in every 30days.

VIII. REFERENCE

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