IJISET - International Journal of Innovative Science, Engineering & Technology, Vol. 3 Issue 1, January 2016.
www.ijiset.com
ISSN 2348 – 7968

Potential of biomass Energy for generation of electricity: Model for small rural area Makori in District Karak KPK and comparison of power generation from sewage sludge of Makori village with that of bara river in Peshawar

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ABSTRACT

Waste obtained from living organisms, including plants and animals is known as Biomass. Energy derived from biomass can be used as a direct source of energy or by converting it into a fuel called as bio fuel. Renewable energy resources have become potential entrant for the achievement of future energy needs keeping in view the current energy requirement and the diminishing sources of fuel. Biomass, being a renewable energy source, is one of the most capable alternatives to the conventional energy resources including mineral oil and natural gas. To exploit biomass in more cost-effective and proficient way, research work is in progress all over the world. Pakistan being a developing country, where fulfillment of energy requirements is a big challenge; power generation using biomass can be useful in order to overcome the energy shortfalls.

This paper describes power generation potential of the waste water of small rural area Makori in District Karak, KPK. It considers the possibility of bio gas run power plant near MOL Production facility. In order to analyze sewage sludge laboratory analysis was performed. Daily sewage sludge discharge data was recorded from the flow meter available at MOL Production facility. Biogas potential was calculated using 10, 20 and 30 days retention time. It was estimated that 261915 m3, 524474m3 and 605559m3 of methane can be produced in a year and the power production was estimated to be 91 kW, 182 kW and 210 kW respectively.

In addition this document also include a comparative study for biogas potential of sewage sludge / waste of two different areas i.e. sewage sludge of MOL Makori plant and sewage sludge of nullah flowing into Bara river Peshawar.

Keywords: Renewable Energy, Biomass, Biogas, Feedstock, Anaerobic digestion, Retention time, Total volatile solid.

I. INTRODUCTION

Fossil fuels are conventional energy sources for over a century now. They, along with nuclear energy, have been researched enough and are highly utilized as the major source for global energy. Although they fuel major portion of energy desire yet at a cost of hazardous impact on the environment due to NOx, CO2, CO and SOx emissions. The implications are in the form of ozone layer depletion, global warming and radioactive nuclear waste. The nuclear energy is clean with respect to emissions, yet its radioactive waste directly affects our ecosystem and creates immediate/long term health issues. In addition to this, these sources lack sustainability and are limited in nature. This has been established now with time and experience that these sources will run-out and alternate sources need to be discovered to cater for future energy needs. The features desired in these sources are sustainability, cleanliness and cheapness [1].

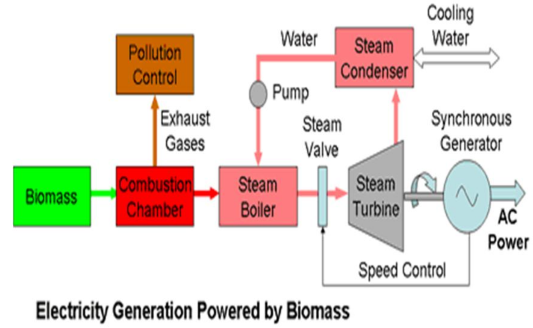

Figure 1: *Process flow diagram of Electricity Generation from Biomass.*

The renewable energy sources are pursued for this purpose as they offer the desired features. They can offer long term solution to energy requirements both on local/international grounds and provide economic solution to energy demand and thus lowers the import bills for fossil fuel [2]. The world is gradually shifting to these renewable sources of

ISSN 2348 – 7968

energy and this can be established from the fact that by 2014, 19% of the world energy demand is met from renewable energy sources (Source: REN21 – Renewable Energy Policy Network for the 21st Century).

Biomass is one of the abundantly available renewable energy sources available round the globe. Its biodegradability is the major advantage – comprising of waste and residues. They are found both in land and in water where it comes from agriculture, forestry, related industries like fisheries, industrial and municipal waste [3].

As the organic material degrades, it generates a gas called Biogas. The production of this gas during degradation is caused by soil bacteria during anaerobic conditions (unavailability of air). The bacteria generate residual organic waste along with biogas due to anaerobic digestion of biomass [4].

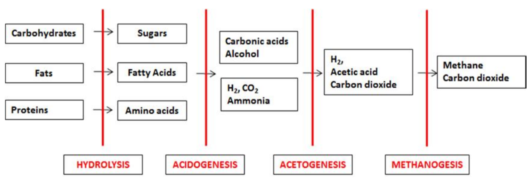

Figure 2: *Keys Step for Biogas production*

Biogas produced is similar to methane gas in many characteristics. Potential of production of biogas of any feedstock depends upon gas yield per KG of total volatile solid (TVS) as shown in the Table 1.

Table 1: Gas Yield per KG of TVS of Some Substrates [5]

Substrate	**Gas Yield (Litres per KG of TVS)**
Pig Manure	340-550
Vegetable Residue	330-360
Sewage Sludge	310-740
Cow	90-310

Biogas yield potential is much dependent on retention time upto large extent. The longer the retention time, the higher the yield is.

Table 2: Percentage Recoveries from Feed stocks at Different Retention Time [6]

Retention Time	**Amount of biogas produced expressed as percentage (%)**		
Time (Days)	**Human Waste**	**Pig Manure**	**Cow Dung**
10	40.7	46	34.4
20	81.5	78.19	74.6
30	94.1	93.9	86.2
40	98.2	97.5	92.2
50	98.7	99.1	97.3
60	100	100	100

The above table shows that biogas yield rate is very high in 10 and 20 days retention time. As evident from the table, a 60 days retention time for human waste will produce biogas at 100% conversion which is not very significant compared to that of 94.1 % conversion from 30 days retention time. Therefore, favorable results can be achieved with a retention time of 30 days.

The composition of biogas depends upon the type of substrate. Biogas generated from human excretion contains 65-66 % methane, 32-34% CO2 by volume and the rest is H2S and other gases in traces while biogas composition for a municipal solid waste is composed of 68-72% CH4, 18-20% CO2, and 8% H2S. Average composition of biogas of different feed stocks is shown in Table 3.

Table 3: Percentage Composition of Biogas of Different Feed Stocks [7]

Gases	**Percentage**
Methane	40-75
Carbon Dioxide	25-40
Nitrogen	0.5-2.5
Oxygen	0.1-1
Hydrogen Sulphide	0.1-0.5
Carbon Monoxide	0.1-0.5
Hydrogen	1-3

For estimation of electricity potential from biogas the following parameters are used.

Table 4: Parameters for Estimation of Electricity Potential of Biogas

Parameters	**Values**
Methane Heating Value [8]	37.78 MJ/m3
Methane Content [9]	65 %
Biogas Engine Efficiency	29 %
Conversion Factor [10]	1 KWh = 3.6 MJ

II. CASE STUDY

Makori is a small village situated in district Karak, KPK province of Pakistan. MOL Pakistan OIL & GAS CO.B.V is a Hungarian based oil and gas exploration & Production Company operating in Pakistan with reserves in TAL block KPK. Two main production facilities of MOL Pakistan namely Manzalai CPF and Makori GPF are both located in Makori village. Both the plants are adjacent to one another surrounded by single boundary wall.

About 1000 workers are employed in both the facilities of MOL Pakistan. A large amount of solid and liquid waste is being generated from the production facilities which includes human excreta and other domestic wastes produced during domestic activities. Solid waste is collected in to large waste bins provided by the management in different locations throughout the facility. The waste is then burnt at site far away from the facility. As for liquid waste, an effluent treatment plant is already installed at the facility for safe disposal of liquid discharge after achieving NEQS standards (National Environmental quality standards). Both liquid and solid waste of MOL plant facilities has enormous potential of biogas yield.

The purpose of this paper is to explore the techniques that could be utilized to acheiver máximum output from the waste produced at MOL Pakistan facilities with main focus on the use of the facilities waster to generate biogás which in turn should be utilized to generate electricity.

This research is carried out with the following considerations;

- Subject matter of this study is power generation potential of the waste water of small rural area Makori in District Karak, KPK.
- It considers the possibility of bio gas run power plant near MOL Production facility.
- Additionally, this document also include a comparative study for biogas potential of sewage sludge / waste of two different areas i.e. sewage sludge of MOL Makori plant and sewage sludge of Canal flowing into Bara river Peshawar.

III. ANALYSIS OF FEED STOCK

. Average biogas produced from 1 kilogram of total volatile solid (TVS) is given by the formula. Biogas SEWAGE, is (310+740) / 2=525 (|0.525 m3) liters of biogas per kilogram of TVS. As clear from below Table 6, TVS found in sewage of MOL production facilities is 45974 mg/liter. Therefore the quantity of TVS available in the waste water (STVSD) is calculated as,

TVSD = TVS X total daily waste (1)
= 45974 (mg/liter) X 112380 (liters/day)
= 2712.44 kg/day

The daily biogas potential of waste water, Biogas DAILY, is given as;

Biogas DAILY= TVSD X Biogas SEWAGE (2)
= 5166.55 X 0.525
= 2712.44 m3 /day

The biogas production from sewage on daily basis is anticipated as Biogas DAILY= 2712.44 m3/day. Three retention times i.e. 10 days, 20 days and 30 days were chosen. Each retention time has its individual biogas recovery percentage as shown in Table 2. Daily biogas production capability from sewage sludge of MOL production plant with respect to each retention time is well described in the below figure 1.

By assuming 65 % of methane in human excreta, the annual methane production from sewage sludge can be calculated from the below equation.

Methane Annual= Biogas DAILY X 365 X 0.65 (3)

Where Methane Annual = Methane Produced annually from sewage sludge of MOL plants.

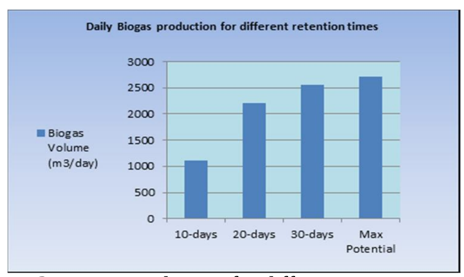

Figure 3: Biogas production for different retention times

Since biogas yield from sewage closely depends upon retention time the annual methane generation will also vary with it. Annual methane generation for retention times of 10 days, 20 days and 30 days is tabularized as under;

Table 5: Annual Methane Estimation for Different Retention Times

Retention Time (Days)	**Annual Methane Estimation (m3)**
10	261915.53
20	524474.6
30	605559
Maximum Potential	643527

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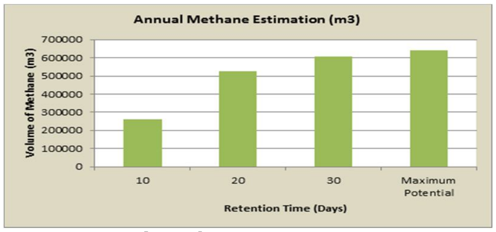

Figure 4: Annual Methane Estimation versus retention times

IV. METHODOLOGY

On average 112380 liters of liquid waste is produced in MOL Pakistan production facilities on daily basis. For the estimation of biogas potential, lab analysis of sample was carried out. Results of the tests carried out are mentioned below;

Table 6: Quality Analysis of Sewage of MOL Production facilities

Variables	Results
Total Solid (TS)	54290 mg/liter
Total Volatile Solid (TVS)	45974 mg/liter

Using this data, annual methane estimation was carried out as per the relevant formulae described above

V. RESULTS

If we assume that the biogas generated will be used to drive power generator that will run for the whole year then size of the generator for every retention time is calculated with the help of following equation with particular reference to Table 4.

Biogas GEN= METHANE ANNUALX 37.78 Mjoule/m3 x 1 (Kwh)/3.6 (Mjoule)x 1 (year)/365 (days)x1 (day)/24 (h) X 0.29 (4)

Where, Biogas GEN = capacity of the generator that will be running on Biogas.

The results in the below table demonstrate clearly that size of the generator and energy produced depend upon retention time.

Table 7: Annual Energy Productions and Generator Sizing For Different Retention Times.

Retention Time (Days)	Annual Energy Production (MJ)	Generator Capacity (KW)
10	9895168	91
20	19814650	182
30	22878019	210

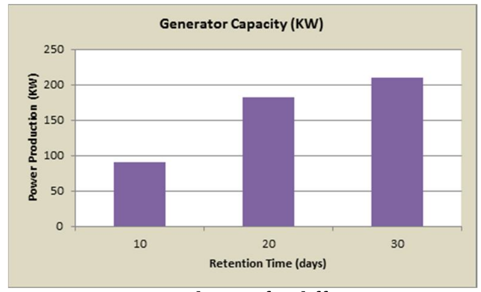

Figure 5: Power Production for different retention time

Justification:

Maximum power which is estimated to be produced from waste water of MOL Production plants is about 210 KW. The amount of power produced is well enough to justify installation of bio gas power plant for Makori village. This is evident from the above calculations that energy generation depends up to large extent on retention time i.e. larger the retention time greater will be the energy and hence power production. The sludge can be treated for longer retention time but it will ultimately increase the digester size resulting in enormous cost implication of the project

V.I. Methane Estimation for sewage sludge of canal flowing into bara river Peshawar

A sample of waste water of the Nullah/Canal was analyzed to find out the concentration of the desired components. Results of the test carried out are tabulated as under:

Table 8: Quality Analysis of Sewage

Parameters	Values
Total Solid (TS)	2697 mg/liter
Total Volatile Solid (TVS)	631 mg/liter

Average flow of the sewage Nullah is 70 cusec or 171260290 liters/day. The Nullah consists of waste water from different locations that mainly contains domestic waste including kitchen waste and human excreta. Therefore, average liter of biogas produced from one kilogram of total volatile solid (TVS) present in sewage, Biogas SEWAGE, is assumed to

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be (310+740) / 2=525 (|0.525 m3) liters of biogas per of TVS. As per the results of waste water analysis, Total Volatile Solid (TVS) were obtained as 631 mg/l. Total amount of TVS that will be produced on daily basis is calculated as per the following formula.

TVS= 631 mg/l

Flow= 171260290 liters/day

Total Volatile Solid Produced Daily (TVSD) =

TVS x Flow

= 631 x 171260290 = 108065 Kg/day

The daily biogas potential of waste water,

BDAILY, is given as;

Biogas DAILY= TVSD X Biogas SEWAGE

= 108065 x 0.525 = 56734 m3/day

As stated above, three retention times of 10, 20 and 30 days were considered. Larger the retention time greater will be the biogas generation potential as mentioned in Table: 2. Daily biogas production rate with the aforementioned retention times is given in the below table.

The daily biogas production from sewage is estimated as B_{DAILY}= 14529 m3/day. Three retention times i.e. 10 days, 20 days and 30 days were selected. Each retention time has its own biogas recovery percentage as shown in Table 2. Daily biogas generation potential from sewage of Hayatabad with respect to the selected three retention times is shown below in figure 1.

If we assume that the amount of methane in human excreta is approximately 65 % the annual methane production from sewage of Hayatabad can be calculated from the following relation.

$$A_{METHANE} = B_{DAILY} \times 365 \times 0.65 \quad (3)$$

Where $A_{METHANE}$ is the annual methane generation from sewage sludge of waste water of Hayatabad.

Figure 1: Daily Biogas Production for Various Retention Times

Since biogas yield from sewage closely depends upon retention time the annual methane generation will also vary with it. Annual methane generation for retention times of 10 days, 20 days and 30 days is tabularized as under;

Table 6: Annual Methane Estimation for Different Retention Times

Retention Time (Days)	Annual Methane Estimation (m^3)
10	1402859
20	2809277
30	3243444
Maximum Potential	3447005

V.II. Power Production Potential

If we assume that the biogas generated will be used to fuel generator that will run throughout the year then size of the generator for each retention time is calculated with the help of following equation with specific reference to Table 4.

As stated above, three retention times of 10, 20 and 30 days were considered. Larger the retention time greater will be the biogas generation potential as mentioned in Table: 2. Daily biogas production rate with the aforementioned retention times is given in the below table

Table 91: Retention Time versus Biogas Potential

Retention Time (Days)	Volume of Biogas Generated (m3/day)
10	23090.84
20	46238.42
30	53386.93
Max. Potential	56734

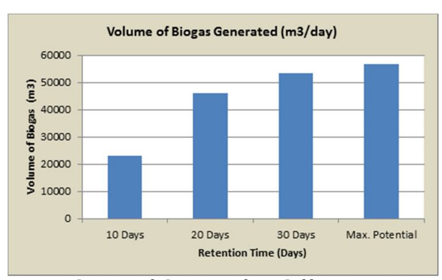

Figure 6: Volume of biogas for different Retention times

As per assumption that the biogas generated shall consist of 65 % methane, annual methane production is calculated through Equation No. 3. Annual methane production is tabulated as under;

Table 10: Annual Methane Estimation for Different Retention Times

Retention Time (Days)	Annual Methane Estimation (m^3)
10	5478301
20	10970064
30	12666050
Maximum Potential	13460201

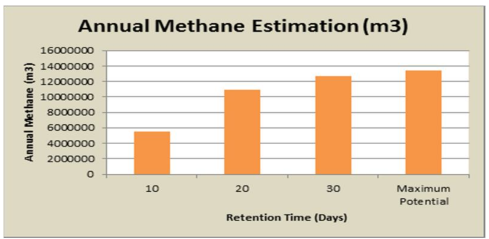

Figure 7: Annual Methane Estimation against Different Retention Times

Power Production Potential:
The biogas obtained will be further used to drive a power generator. Power generation capacity is calculated using Equation No. 4. Annual energy production and capacity of biogas generator against different retention times are shown in the below table.

Table 11:Annual Energy Productions and Generator Sizing For Different Retention Times

Retention Time (Days)	Annual Energy Production (MJ)	Generator Capacity (KW)
10	206970248.8	1903
20	414449023.9	3811
30	478523351.6	4400

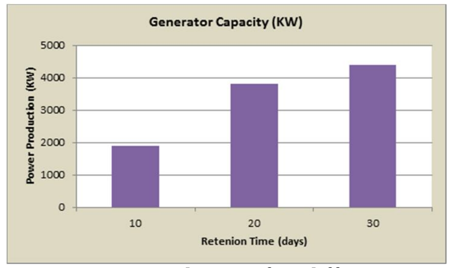

Figure 8: Power Production for different retention time

Keeping in view the above facts and figures, it is crystal clear that annual energy production and generator capacity enhances with increase in retention time. Nevertheless, greater retention time will entail a digester of much bigger size. Even though expenditure of biogas power plant with much bigger size will be high yet at the same time it will provide an excellent water treatment system and manure of high-quality in addition to the production of massive heat.

VI. CONCLUSION

Development of Renewable energy (RE) is playing a key role in Energy and power sector development strategy of any country. Our Country has immense potential and resources of Renewable energy that includes solar, wind, biomass and small to medium hydro power. If proper planning and arrangement are done then sources of RE may add significantly to meet the energy demand in the country. Power/ energy obtained from RE can be included in both off grid and grid connected power requirements. Besides the energy addition, these contributions have other benefits like rural growth, support for monetary activities in distant areas and positive environmental and social impacts.

The above study demonstrates that Nullah near ring road waste water treatment plant which ultimately flows in the Bara River of Peshawar has massive potential of biogas generation. With retention time of 30 days it can produce electrical power up to 4400 KW which can feed power supply to approximately 400 houses having average load of 11 KW each. Similar studies can be carried out for other waste water channels.

Apart from waste water solid waste can also be used to generate biogas. According to a report urban areas of Pakistan produce solid waste of more than 50000 tons per day. Layer chicken of more than 15 million and broiler chicken of more than 528 million were approximately produced in 2003. Punjab, Sindh, KPK and Baluchistan

ISSN 2348 – 7968

provinces had a share of 69%, 21%, 6.4%and 3.6% respectively in it.

The subject study reveals that by the use of biogas technology Pakistan can overcome power shortages using green energy at reasonable rates. Currently Pakistan is facing power shortage of approximately 6000 MW. Installation of biogas power plants in major cities would not only reduce environmental pollution but also an alternative power source mitigating the existing energy crisis in the country.

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