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Evaluation of the Potential use of Bagasse and Sugar Millswaste Water as Substrate for Biogas Production

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Abstract**—***Biogas is a sustainable alternative source of energy to fossil fuels. Its production also serves as sink for biological wastes and it is a pollution control measure. Most of biogas generation units in Kenya utilize animal wastes as the substrate. However, the bio fuel potential of bagasse, the abundant crop residues like co-products in sugarcane-based industries remain underutilized. The idea of converting bagasse into additional energy is gaining attention, especially through government commitments on increasing the renewable energy generation combined with the reduction of carbon dioxide emissions. In this study bagasse samples collected from Chemelil sugar mills were passed through multiple sieves of different sizes to obtain different particle sizes. Mills waste water was also collected from Chemelil sugar factory and analyzed for pH and Total Dissolved Solids (TDS) to establish their biogas production potential, the analyzed mills waste water was then mixed with different particle sizes of bagasse and allowed to be digested anaerobically. Volume of the gas collected from each flask containing different particle sizes of bagasse was measured to identify the optimum conditions for biogas production. The study showed that the mills waste water that had the highest TDS (130g/L) yielded relatively higher volumes of biogas when mixed with bagasse of different particle sizes. Bagasse of particle size ≤0.600mm produced the highest volume when mixed with the mills waste water with TDS and pH of130g/l and 4.67 respectively. Designing and installing a digester system that allows for the control of TDS and pH in mills wastewater and utilizes bagasse of particle size ≤0.600mm would be expected to produce reasonable amount of biofuel and put a check on environmental pollution problems associated with bagasse and sugar mill waste waters in sugar factories.*

Keywords— Bagasse, biogas, mill waste water, pH and TDS.

I. INTRODUCTION

Biogas refers to a mixture of different gases produced by the breakdown of organic matter in the absence of oxygen. Biogas can be produced from raw materials such as agricultural wastes (e.g. Sugarcane bagasse, animal excreta), domestic wastes and industrial wastewaters. Bagasse is the fibrous matter that remains after sugarcane is crushed to extract its juice. Sugarcane based industries are among the most promising agricultural sources of biogas energy in Kenya from abundant co-products of bagasse and waste water. However, the Kenyan Sugar industries are yet to embrace technologies that could utilize the wastes in the production of biogas and fertilizers. The bagasse waste is often left to decompose outside the sugar factories (Figure 1.1), thus contributing to environmental pollution and consume the much needed space in and around the factories.

The accumulated bagasse are common features in and around sugar milling facilities putting water bodies around the factories under constant threat of pollution by both leachates from the bagasse and waste water from the factories. Anaerobic digestion of sugarcane waste can be considered a promising strategy since the slurry could still be used to partially replace the mineral fertilizers on the sugarcane fields and the produced biogas could be upgraded to bio methane and sold as a new energy product by the sugarcane manufacturing firms. The sum of these being a fermentation which converts a wide array of substrate materials, having carbon atoms at various oxidation/reduction states, to molecules containing one carbon in its most oxidized (CO_2) and the most reduced (CH_4) state. Minor quantities of nitrogen, hydrogen, ammonia and hydrogen sulphide(usually less than 1% of the total gas volume) are also generated [13].The principal objectives of recycling bagasse and waste water are generally to allow industrial effluents to be disposed of without posing risk to human health and to prevent unacceptable damage to the natural environment. Since cost effectiveness is one of the key considerations in any production process, it is imperative to identify and profile the major waste products from sugar industries that could be used for other economic gains as a way of environmental pollution control.

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Fig,1.1: Accumulated bagasse waste outside Sony sugar factory

Similarly waste water from the sugar production processes and cleaning operations in the factories end up into surface water bodies. The recipient water bodies are at risk of chemical pollution, thermal pollution and eutrophication (Figure 1.2) shows accumulating wastewater from Chemelil sugar factory, in Kisumu County.

Fig.1.2: Waste water around Chemelil sugar factory

Bagasse is the fibrous matter that remains after sugarcane is crushed to extract its juice. According to [4], accumulation of greenhouse gasses in the atmosphere and limited fossil fuel reserves, a transition away from fossil fuel is necessary. Bagasse has got the potential for being used for biogas generation as studied by [6] and can reduce the reliance on fossil fuel. Study by [10] show that the annual production of dry cut sugarcane is about 328 million tons and after sugars have been extracted about 180 million tons of bagasse remain which could be used in biogas production However, in Kenya some bagasse is burned for process heat in sugar mills and distillers [1].

Excess bagasse is left to decompose outside the industries and is likely to be a source of environmental pollution.

Bagasse is a lignocellulosic biomass primarily composed of cellulose (38 to 45%) hemicellulose (23 to 27%) and lignin (19 to 32%) [5]. Today new enzyme cocktails developed for scarification of lignocellulose contain high β glycosidase activity and lytic polysaccharides mono oxygenases, LPMOs [3],[9],[4] and may also include better and more stable cellulose. Overall these improvements have led to considerably more efficient enzyme cocktails [2] that will help in the digestion of bagasse to generate biogas.

For optimum biogas production, sugarcane bagasse residues should be harvested within their growing period as fresh. The drier and straw-like the plant, the less biogas it produces [7]. [11]Stated that Bagasse substrate should be chopped into smaller pieces in order to increase the surface area for hydrolytic enzymes to attack and thus to release more soluble components. However, they never specified the specific size in which the bagasse particles should be chopped. In this work the optimum size of bagasse was determined and recommendations made. Recently, the concept of the bio refinery has received considerable attention as an alternative route for biomass exploitation, based on integrated combined processes for the simultaneous generation of energy, fuel, and value – added products [8]. As an abundant waste, bagasse could be used for production of sig Wastewater is any water that has been adversely affected in quality by anthropogenic influence.

This water are collected and channeled into a common treatment plant after which they are being discharged back to the river. This waste water contains a lot of sugar that can aid fermentation process.

II. METHODOLOGY

2.1.1. Area of study

Study was carried in University of Eldoret School of Agriculture Chemistry laboratory at 2,100 meters above sea level. At 00 34' 43"N and 350 18' 21" E.

The project samples were collected from Chemelil Sugar Company located in in Kisumu County, Kenya. The field work involved visiting the company and collecting samples of the waste water from the five sources of the waste water in the industries i.e. sugar process house, juice treatment, mills water, V – notch water, anaerobic pond. The samples were collected on 23rd May 2016

2.2. Types of tests on industrial waste water

Waste water was collected in a clean three litre tin from five locations of the sugar mill and was carried to the University laboratory for analysis. The locations were; Sugar process house, Juice treatment house, Mill waters, V – Notch water and anaerobic pond.

2.2.1 Determining Total Dissolved Solids (TDS)

Total dissolved solids (TDS) is defined as "the combined content of all inorganic and organic substances contained in a liquid that are present in a molecular, ionized or micro granular suspended form." TDS is measured on a quantity scale, either in mg/L or, more commonly, in parts per million (ppm). In this study the TDS was determined in the laboratory using the following setup and procedure.

2.2.2Apparatus

Porcelain dish, Hot plates, Measuring cylinder,
Beaker,Weighing balance.

2.2.3 Procedure

The empty porcelain dish was weighed and weight recorded. Using the measuring cylinder equal volume of 50ml of the industrial water was measured and added to the pre-weighed porcelain dishes labelled differently for different samples. The samples were then placed on hot plate until all the water evaporated. The set up was as shown in figure 3.1 below

Fig.2.1: sample of waste waters on hot plate

2.3 pH

The term pH refers to the measure of hydrogen ion concentration in a solution and defined as the negative logarithm of hydrogen ions concentration ($-Log_{10}$ [H+] in water, wastewater or a solution. The values of pH 0 to a little less than 7 are termed as acidic and the values of pH a little above 7 to 14 are termed as basic. When the concentration of H+ and OH– ions are equal then it is termed as neutral pH, and corresponds to a value of 7.

Wastewater was collected in cleaned tins from different sources in the factory and labelled using stickers. Their pH was measured using pH meter using the procedure shown below.

2.3.1 Procedure.

- 15mL of each of industrial waste water was poured into separate 30mL beakers.
- pH electrode was then connected to the meter

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- The protective cap was then removed from the electrode and rinsed. The electrode was shaken gently to remove excess water
- The electrode was then immersed into the waste water. The electrode should be submerged at least 1.5cm into the water poured in the beakers.
- The electrode cap was then rinsed with deionized water to remove any residues and to dry in air.
- Press the "ON/OFF" button. Note that buttons have a delayed response and holding down lightly for a couple of seconds is required to get a response.
- If "CAL" does not appear on the left of the screen, press and hold down the "CAL" button and the left side of the screen will flash "NOT READY "until the meter reading stabilizes.
- Repeat the procedure for other samples

The set up was as shown in figure 3.2 below.

Fig.2.2: pH meter being used to measure sample pH

2.4. Determination of the bagasse particle size

The bagasse sample was collected in clean dry polythene from Chemelil sugar factory and was carried to the university laboratory for analysis. The sample was dried inside glass green house as shown in figure 3.3 below prevent the smaller particles from being carried away by wind.

Fig.2.3: Bagasse being dried before grinded.

2.4.1 Apparatus and materials

Mechanical shaker, Bagasse, Brass, Sieves of the different sizes(1.0mm, 0.6mm, 0.425mm, 0.3mm, 0.212mm, 0.15mm),Pastle and mortar.

2.4.2 Procedure

The sieves were cleaned to remove all residues from previous experiments. Small portions of bagasse were added to the mortar and ground using into smaller sizes. The sieves were then arranged in descending order of sizes and the bagasse was added in the top sieve then clamped on the mechanical shaker. The set up was the shaken thoroughly for 20 minutes. The set up was as shown in figure 3.4 below.

Fig.3.4: Mechanical shaker and sieves

2.5 Experimental set up for biogas production

The various samples of waste water obtained from various sources in the factory and different particle sizes of bagasse were mixed to react in order to produce biogas.

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2.5.1 Procedure

Five conical flasks were cleaned and rinsed thoroughly using clean distilled water and labelled using stickers, labelling was done in descending order of particle sizes. The bagasse sample was then weighed and poured into different conical flask as shown in the table below.

Table.2.1: Particle size and water added

Labelled	Particle size of bagasse	Water added
Flask 1	1.000mm	Sugar process house
Flask 2	0.600mm	Juice treatment house
Flask 3	0.425mm	Mills waters
Flask 4	0.300mm	V – Notch water
Flask 5	0.215mm	Anaerobic pond.

The mills waste water collected from various sources was then measured using measuring cylinder and added to the conical flask in and stirred using stirrer in order to mix with the bagasse, the conical flask was then closed using a cork fitted with a straw that allows the delivery of the gas generated. The gas was collected using non – porous plastic polythene bags, the set up was then stored in a safe place for twenty days to react and generate the gas. The set up was as shown in the image below.

Fig.2.5: Set up for biogas production

The set up was monitored daily and the reaction rate was observed and changes in the conical flask were noted, increase in size of the polythene bag and accumulation of moisture on the walls of some conical flask were also observed as shown in figure 2.6 below

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Fig.2.6: vapour condensing on walls of conical flask

After the retention period was attained, the gas collected in the polythene bag was carefully removed from the setup, its mass was measured and the volume was estimated through assuming the density of methane to be 0,656Kg/m^3 since it is the most abundant gas in the mixture. The results obtained were as shown in table 4.1.

III. RESULTS AND DISCUSSIONS

3.1 Determination of TDS.

The results of the experiment to determine the TDS of various water samples collected from the factory is as shown in the table 4.1 below. The values of TDS we calculated; For example, for sample 1

TDS = 0.032 x 1000 = 32g/l

Calculation was repeated for the entire to obtain various values of TDS of the remaining samples and results

Table.3.1: TDS values for wastewater samples from Chemelil Sugar Factory

Sample	Weight of empty tin (g)	Resultant weight after evaporation (g)	Weight difference	TDS (g/l)
Sample 1	25.5	27.1	1.6g	32g/l
Sample 2	33.6	40.1	6.5g	130g/1
Sample 3	33.2	34.5	1.3g	26g/l
Sample 4	24.8	27.6	2.8g	56g/l
Sample 5	33.1	34.9	1.8g	36g/l

3.2 Results of pH of the waste waters.

Table.3.2: pH values for wastewater samples from Chemelil Sugar Factory

Sample	Source of the sample	pH value
Sample 1	Sugar process house	4.28
Sample 2	Juice treatment house	4.67
Sample 3	Mills waters	5.14
Sample 4	V – Notch water	5.44
Sample 5	Anaerobic pond.	5.60

Table.3.3: Results of volume of gas generated

Flask	Particle size	Weight of gas generated + polythene bag (g)	Weight of the gas (g)	Volume of the gas (cm^3)
Flask 1	1.000mm	0.08g	0.07g	10.67cm^3
Flask 2	0.600mm	0.10g	0.09g	13.72 cm^3
Flask 3	0.425mm	0.07g	0.06g	9.15cm^3
Flask 4	0.300mm	0.06g	0.05g	7.62cm^3
Flask 5	0.215mm	0.02g	0.01g	1.52cm^3

Assumptions made in this calculation was that the overall density of the biogas was taken to be 0.656kg/m3 which is the density of methane since it is the highest portion of the gas generated i.e.
68% of the total volume.

3.4 Data presentation

3.4.1 Particle size against volume

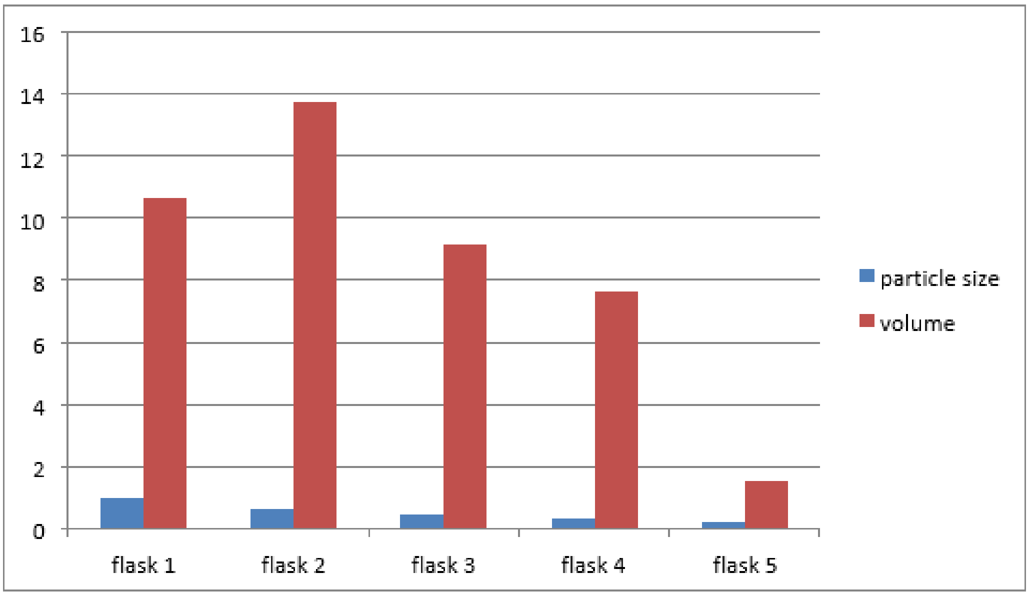

Fig.3.1: Graph showing particle size against volume

3.4.2 TDS against volume

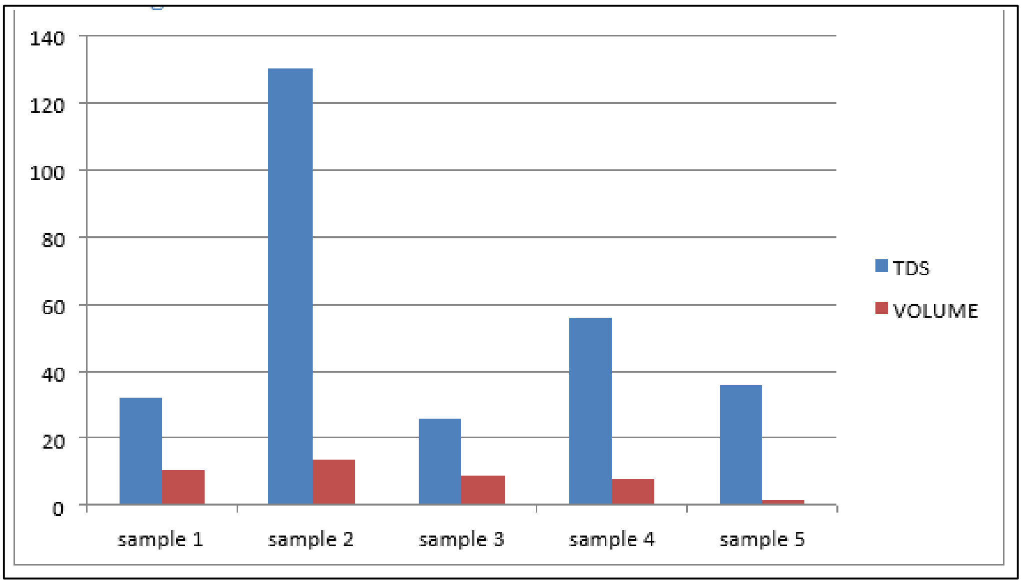

Fig.3.2: Graph showing TDS against Volume.

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3.4.3 pH Against Volume

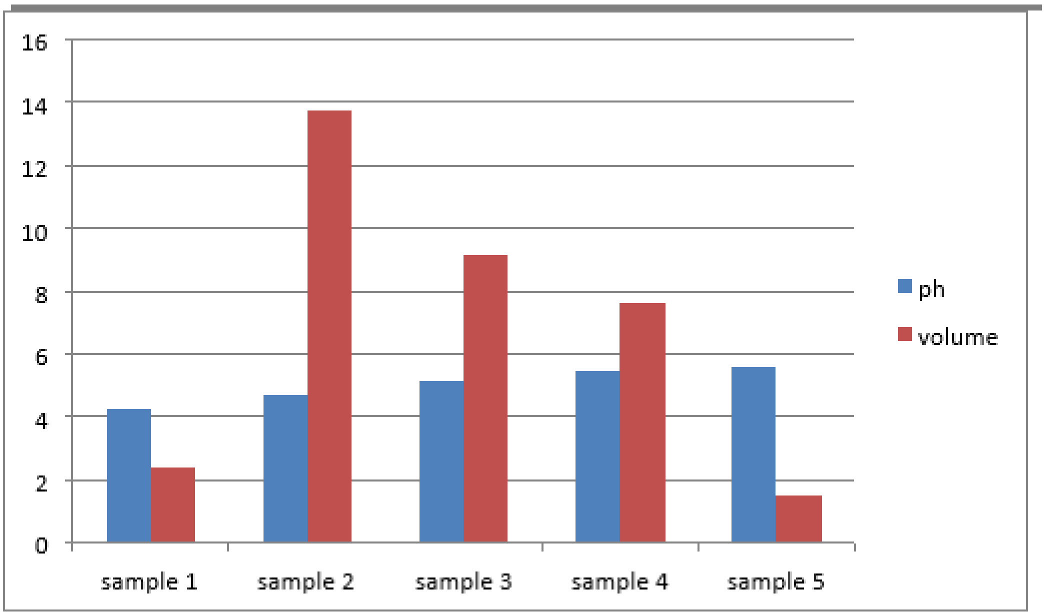

Fig 3.3: Graph showing pH against volume

3.4.4 Comparison of pH, particle size, TDs and volume

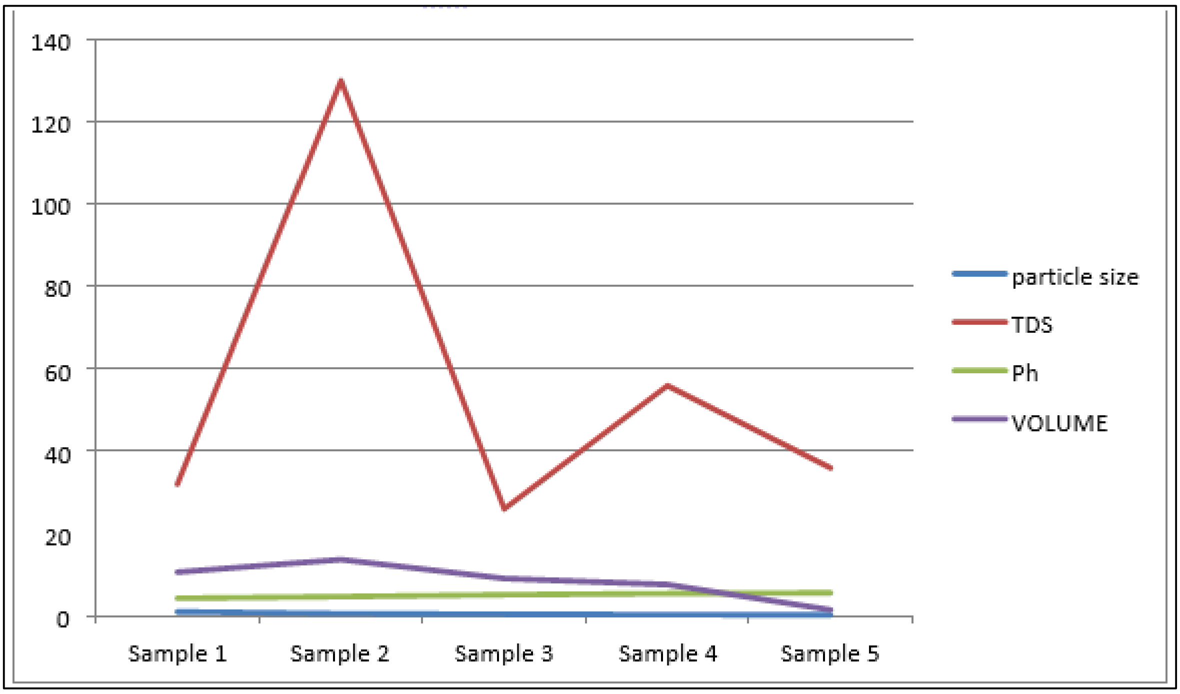

Fig.3.4: Graph showing comparison of pH, particle size and TDS against volume of biogas

3.5 Discussions

The biogas components and biogas yield depend on feed materials due to the difference of material characteristics in each raw material [12]. Different particle sizes of bagasse and different quality of waste water were investigated to determine characteristics of biogas production. In this study, the experiment had been done in natural condition. The characteristics of biogas production using different particle sizes and different quality of mills waste water are discussed as follow.

3.5.1 Influence of pH on biogas production

At pH 4.67, the volume of biogas generated was more compared to pH of 6.69, this was because the mills waste water was probably in the initial stage of fermentation due to presence of sugar and the bacteria present were already active to digest bagasse particle sizes. In this study the optimum pH ranges from 4.67 – 5.44, this confirms the study by [14]on influence of pH on anaerobic process.

3.5.2 Influence of particle size on biogas production

Particle sizes of bagasse play an important role in biogas production. The smaller particle sizes are readily digested by anaerobic bacteria than the larger ones. In this experiment the optimum particle size that yielded high volume of biogas is observed to be 0.6mm. This is because this size contains less fibers and dust particle hence can easily be digested by anaerobes bacteria to generate biogas. Smaller particle sizes were observed to generate less volume of biogas due to the fact that they are mixed with other smaller particles like soil that don't contain nitrogen element which is responsible anaerobic digestion. Particle size of 1.00mm produced good volume of biogas due the influence of the waste water used which contained high level of microorganism that digested portion of the bagasse substrate.

There is a general trend of decrease in volume of biogas produced as the particle sizes of bagasse reduces as shown in (Figure 4.1.), in the second conical flask the volume was observed to be high due other factors.

3.5.3 Influence of TDS on volume of biogas production

The volume of biogas generated was observed to be high in flask 2 which contained water with a TDS of 130g/l. This is because high TDS shows high presence of microorganism and other impurities that will generate maximum biogas. In the flask where water of low TDS was added less volume of gas was generated due to presence of less number of anaerobes that digest bagasse particles as shown in Figure 4.2

3.5.4: Comparison of the TDS, pH, TDS, particle size on volume of gas produced.

As can be seen in Figure 4.4 the volume of biogas generated varied in different direction depending on the parameters that was observed. The volume of gas produced was observed to be highest in wastewater sample, drawn from juice treatment house, which had TDS of 130g/l, pH of 4.67, mixed with Bagasse of particle size of 0.600mm. This can be taken as the optimum conditions for the use of bagasse and industrial waste water.

IV. CONCLUSION

Anaerobic fermentation for biogas production is very complex reactions which involve many intermediate compounds and microorganisms that play important role in the process. This study evaluated the potential of different particle sizes of bagasse and different qualities of waste water in terms of TDS, pH of the mills waste water, in production of biogas.

The result can be concluded as follows:

a) High level of TDS in mills waste water catalyzes biogas production when mixed with different particle sizes of bagasse.
b) The biogas production was highest when using bagasse of particle size 0.6mm due absence of foreign particles and absence of fibrous matter content that has less nitrogen content hence this size appeared to be the most suitable to be used in digesters.
c) The variation in volume of biogas produced in various set up was mainly dependent on TDS level and pH.

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