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Filtration of biogas spent slurry and it's chemical analysis

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Abstract
The biogas spent slurry dewatering mechanism was developed at Department of Renewable Energy Engineering, CTAE Udaipur to filter biogas spent slurry. The prime purpose was to separate water from the biogas spent slurry so that it will be feasible to transport. The mechanism was evaluated for performance at different bed thickness such as 10, 7, 5 and 3.5 cm. For above mentioned bed thickness the drying time was 20, 17, 13 and 8 days respectively. At 3.5 cm the biogas spent slurry was filtrated using maize and sorghum stalk as filter material. To some extent the agricultural waste material helps to retain nutrients such as Nitrogen, Potash and Phosphate in the dried slurry. Amongst them the best results were given when maize stalk used for filtration.

Keywords: Biogas spent slurry, Dewatering mechanism, Maize stalk, Sorghum stalk, Nitrogen, Potassium and Phosphate

1. Introduction

Biogas production technology is based on the phenomenon of biological decomposition of organic materials in the absence of air. "Biogas" is a gas produced by anaerobic fermentation of different forms of organic matter and is composed mainly of methane and carbon dioxide. Typical feedstocks for biogas production are manure and sewage, residues of crop production (i.e. straw), the organic fraction of the waste from households and industry, as well as energy crops including maize and grass silage. Generally farmers use the digested slurry to leave in the nearby area of plant such or some time it is disposed in nearby watercourse. Some users transport it as much in the fields and left in irrigation channels so that it can reach crop through water. (Hjorth *et al*, 2009) [4] This tends to high transport cost because of high moisture content and uneven distribution of digested slurry in the field.

Biogas spent slurry displays high water content of almost 90%, raising the issue of whether it should be dewatered and dried before application within agriculture. On the other hand, upon drying up to 90 % (Arthurson, 2009) [9] N_2 may be lost as ammonia which would dramatically reduce the benefits of biogas residue as a crop fertilizer. The liquid portion of the slurry is being separated from the solids has many advantages for its reuse either in gas plant or using it as a starter culture for composting. The digested slurry contains about 1.5 to 2.0 % Nitrogen, 0.8 to 1.2 % Phosphate and 0.8 to 1.0 % Potash (Mahajan, 1997) [6]. These values are almost double of that found in FYM. In addition to that, the digested slurry has the traces of some major micro nutrients i.e. Zinc, Boron, Calcium, Copper, Iron, Magnesium and Sulfur which are necessary for growth and development of crops. (Kaushik *et al*, 2007) [5].

A considerable quantity of plant nutrients is lost from the digested slurry if sun dried. Therefore it is better to use the fresh wet slurry or partially dehydrated as manure to the crops. In that form it will be easy to transport it to fields, without or with minimum loss of nutrients. As said earlier the most commonly followed method for dewatering is sun drying but this method has many demerits such as uneven drying, loss of nutrients and many more. (Tiwari *et al*, 2000) [10]. To overcome this many mechanical separators were developed but they are having high cost. Hence small stake holders can't afford these huge machineries. Hence small dewatering mechanism was developed which will simply separate water from the spent slurry by using gravity and abundant sunlight.

2. Material and methods

The biogas slurry dewatering mechanism was developed at Department of Renewable Energy Engineering, CTAE Udaipur having length of 3 m and width of 1.3 m with total drying capacity of 80 ± 20 kg = 100 kg because 80 kg slurry is available from 2 m^3 biogas plant. The developed biogas slurry dewatering mechanism is shown in Fig. 1.

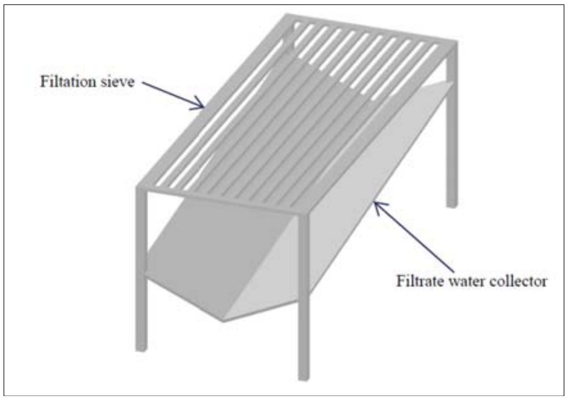

Fig 1: Biogas slurry dewatering mechanism

2.1 Analyzing performance of developed slurry dewatering mechanism

The biogas slurry dewatering mechanism was evaluated for performance at 10, 7, 5 and 3.5 cm respectively. The drying will be relatively faster because large surface area of slurry is exposed to the direct sunlight. Then daily moisture content of slurry recorded so that the moisture deduction rate is noted. The parameters to be recorded are moisture content, total solids and volatile solids.

2.2 Moisture content

The moisture content in samples was determined by drying a weighed sample to constant weight in an oven at a temperature of 105ºC for 24 hours. The loss in weight was used to calculate the per cent moisture in the sample. (Banik and Nandi, 2000)

$$\text{Per cent moisture} = \frac{(B - C)}{(B - A)} \text{ X } 100$$

A = Weight of the sample box, g
B = Weight of the sample box + sample, g
C = Weight of the sample box + sample after drying at 105°C till 24 hrs.

2.3 Determination of total solids

$$\text{Total solids} = \frac{(C - A)}{(B - A)} \text{ X } 100$$

Where,
A = Weight of empty crucible, g
B = Weight of crucible + wet slurry, g
C = Weight of crucible + oven dried material, g

2.4 Determination of volatile solids by using Muffle Furnace

The volatile solids content is determined by using muffle furnace at 550 ^{0}C. (Sekar, 2012)

$$\text{Per cent volatile solid} = \frac{(B - C)}{(B - A)} \text{ X } 100$$

Where
A = Weight of silica crucible, g
B = Weight of crucible + dry matter before ignition, g
C = Weight of crucible + sample after ignition (ash), g

2.5 Nitrogen content

The nitrogen content was determined by method 8075 and for that digestion is required which was carried out in Total Kjeldahl apparatus (Hach *et al*, 1987). The equipments and chemicals required for analysis are boiling chips, silica carbide, cylinder graduated mixing, hydrogen peroxide, mineral stabilizer, nessler reagent, polyvinyl alcohol dispersing agent, potassium hydroxide standard solution, sulfuric acid, TKN indicator, pipet, safety shield and sample cell. The stepwise procedure mentioned in Hach *et al*, 1987 was followed to determine Nitrogen content.

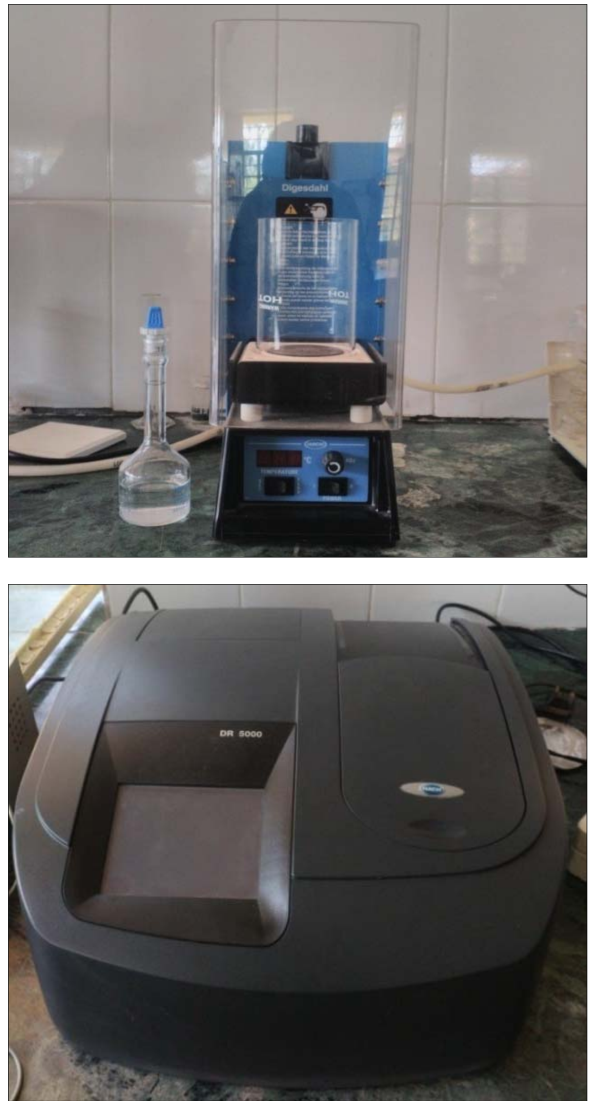

Fig 2: Total Kjeldahl apparatus with Spectrophotometer

2.6 Phosphate content

The Phosphate content was determined by method 8190 adapted from standard methods for the examination of water and wastewater. The result of the reactive phosphorous test after the digestion was included in the orthophosphate and acid-hydrolysable phosphate. The condensed phosphate concentration was determined by subtracting the result of an orthophosphate test from the result. The chemicals required for analysis were potassium per sulfate powder pillows, sodium hydroxide solution, sulfuric acid solution, deionized water, graduated cylinder, Erlenmeyer flask and hot plate. The stepwise procedure mentioned in Hach *et al*, 1987 was followed to determine Phosphate content.

2.7 Potash content
To analyze Potash content method 8049 was followed and before starting the test program 905 had a calibration curve for potassium, however due to potential variation, a new calibration for each lot of reagent to obtain best accuracy was performed. Calibration was done and stored as per manual. The equipments and chemicals required for analysis were potassium reagent 1 powder pillow, potassium reagent 2 powder pillows, potassium reagent 3 powder pillows, potassium standard solution, 100-mg/L, clippers, mixing cylinders, volumetric flask, pipette, sample cells and deionized water. The stepwise procedure mentioned in Hach *et al*, 1987 was followed to determine potash content.

3. Result and discussion
The observed and recorded data on various aspects of the experiment was analysed to interpret the results of physio-chemical analysis of the biogas slurry was done for comparison of moisture content, waste water recovery, plant nutrient content viz. Nitrogen, Phosphate and Potash. The observed data was analysed to get optimum bed thickness and effective method to dry biogas spent slurry.

3.1 Analyzing suitable bed thickness for drying
The biogas slurry dewatering mechanism was evaluated with different thicknesses of drying such as 10, 7, 5, and 3.5 cm. The drying thickness is directly proportional to drying time i.e. if drying thickness increases then drying time also increases. The comparative drying rate at 10, 7. 5 and 3.5 cm bed thickness can be analyzed from Fig.3.

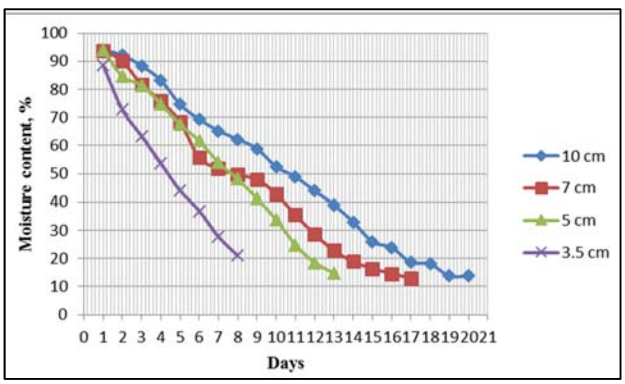

Fig 3: Comparative performance at different bed thickness

It is clearly seen from the graph that as bed thickness of drying increases, the drying time also increases. At 10 cm bed thickness, it took 20 days to deduce moisture content from 94 to 13 %. This is not feasible because time requirement for drying is higher. At this bed thickness the major drawback is choking which was faced initially and it requires continuous stirring. At 7 cm bed thickness, it took 17 days to deduce moisture from moisture content of 93 to 12 % which is again higher. Again the loss of nutrients such as N, P and K was higher in both bed thicknesses. At 5 cm bed thickness, it took 13 days to deduce moisture content from 94 to 15 %. This was again high. Last but not least, the performance was analyzed at 3.5 cm bed thickness in which it took 8 days to dry biogas spent slurry from moisture content of 88.63 to 21 % which is better than any other bed thickness. The biogas spent slurry was dried with different agricultural waste material such as maize stalk and sorghum stalk. The reason behind use of this material is to retain N, P and K content of slurry.

3.2 Analyzing performance of dewatering mechanism with Sorghum stalk
The performance of biogas slurry dewatering mechanism was analyzed with sorghum stalk as filter material. It not only absorbs moisture but also improves nutrient content of dried slurry. On first day the moisture content of the slurry was 91.86 % and per day moisture content reduction rate was 9-10 % because larger area of bed was exposed to sunlight. It took 9 days for mechanism to deduce moisture from 91.86 % to 19.02 %. The spent slurry was partially dried to retain nutrients such as nitrogen, potash and phosphate in the slurry. The nutrient content of the slurry was analyzed by using Total Kjeldahl apparatus.

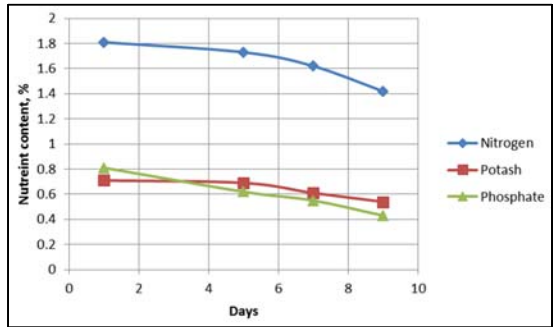

Fig 4: Nitrogen, Potash and Phosphate content of slurry. (Sorghum stalk)

It is clearly seen from the figure that, on the first day the nitrogen, potash and phosphate content of the slurry was 1.8, 0.7 and 0.8 %. It is obvious that as moisture content of the slurry decreases the nutrient content also decreases but it was less as when dewatering mechanism was evaluated for performance without any agricultural waste material. On 9th day the nutrient content were 1.4, 0.5 and 0.4 % respectively which were much higher if conventional method such as pit drying is used for drying of biogas spent slurry.

3.3 Analyzing performance of dewatering mechanism with Maize stalk
The performance of biogas slurry dewatering mechanism was analyzed with maize stalk as filter material. The purpose behind use of this waste material because not only retains nutrient content but also improves nutrient properties of dried slurry by decomposing itself. The biogas spent slurry was spread on drying platform, on first day the moisture content of slurry was 93.46 %. The average per day moisture reduction rate was 8 to 10 % per day. It took 9 days to deduce moisture from 93.46 % to 17.29 %. The chemical analysis of dried slurry showed following results.

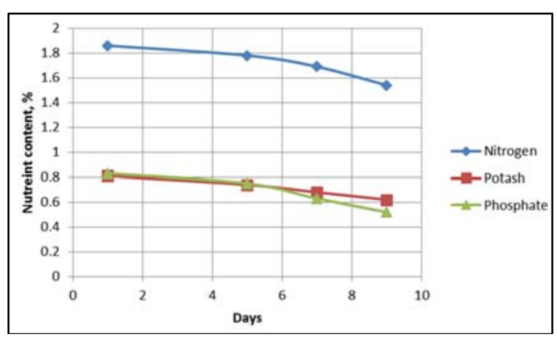

Fig 5: Nitrogen, Potash and Phosphate content of slurry. (Maize stalk)

The graph is plotted between days on which nutrient content determined and amount of nutrient present in the biogas spent slurry. On the first day when experiment was started the Nitrogen, Potash and Phosphate content was 1.86, 0.81 and 0.83 %. It is clearly seen from the Fig.5 that all three components i.e. Nitrogen, Potash and Phosphate decreased with time. The Nitrogen content was decreased from 1.86 to 1.78 on 5th day and it was stabilized at 1.54 on last day experiment. Both Potash and Phosphate content was near about same on first day when slurry having moisture content of 93.46 % and both these nutrients decreased with time but Potash was stabilized at 0.62 and Phosphate was stabilized at 0.52 %.

3.4 Solid and Volatile Solid Content

One of the major process parameter which affects the generation of biogas is the concentration of solids in the substrate. The solid content of the substrate is represented in the form of total solids and total volatile solids. However the area of research field is to investigate the drying performance and nutritional status of biogas dried slurry. If the solid content of filtrate was more than the filtration material is not efficient and suitable for use. Volatile solids contain biodegradable and non-biodegradable parts and this includes soluble and insoluble organic compounds. The soluble organics are capable of being utilized directly as a growth substrate whereas insoluble organics are converted to soluble organics by enzymatic hydrolysis. Amount of total volatile solids in the substrate gives indication of capability of biogas production. The volatile solid content of biogas spent slurry before drying was calculated and presented in Table 1 and 2.

Table 1: Solid content of spent slurry.

Number of trials	Solid content of the dried slurry, %			
	1	2	3	Average
Sorghum stalk	6.74	9.62	8.38	8.24
Maize stalk	3.59	7.07	8.74	6.46

Table 2: Volatile solid content of spent slurry (Shed Net)

Number of trials	Volatile solid content of the dried slurry, %			
	1	2	3	Average
Sorghum stalk	76.74	79.62	78.38	78.24
Maize stalk	73.59	77.07	78.74	76.46

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