Development of Low-Cost Water Heater Using Cow-Dung

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Abstract

India being an agriculture dominated country has large amount of livestock as it is required for the agricultural activities. The livestock not only provides milk and meat but also provide dung as a waste from animals. It has been observed that animal dung-based biomass has large potential in the area of greener energy sources. Out of the total animal dung produced only a fewer portion of it is used for local level activities like burning fuel, manure and other household purposes. Whereas the rest is just a surplus amount left in form of piles in the villages.

In this paper, we have focused on the heat extraction specifically from cow dung through aerobic decomposition process i.e. composting. Cow dung is rich in organic matter, the microbial breakdown of which can result in release of tremendous amount of heat, which can be utilized in form of electricity or heat for air and water. Further this concept can be extended to large amount of municipal waste generated in urban areas.

Introduction

Energy demands are increasing very rapidly these days, hence it has become important to look for alternative and cleaner energy sources. Bioenergy can be seen as a primary possibility for preventing global warming. Also accompanying the benefits of livestock and animal dung, comes the responsibility of its proper disposal. Farmers generally use some portion of dung as fertilizer, domestic purpose and also for biogas at local level. The rest of it is dumped in storage areas or as lagoons. The appropriate use of the dung will be to use it as biomass energy, which ultimately helps us to reduce cost and energy associated with this waste management. One such way of converting biomass to a usable form is composting.

According to Cornell University, composting cycle includes three main stages in which different type of microorganisms thrive. The first stage lasts a couple of days in which

the mesophilic microorganisms begin breaking down the biodegradable compounds. Heat is produced as a by-product of this process. The temperatures in the system reach up to 45°C. In the second stage, the mesophilic microorganisms are replaced by thermophilic microorganisms. This stage lasts for a few months. The temperature continues to rise around 65°C during this stage. The third stage, which typically lasts for several months, begins when the thermophilic microorganisms use up the available supply of the compounds. In this stage, temperatures begin to drop and mesophilic microorganisms take back the control and finish breaking down the remaining organics matter into usable humus.

The first and second stages in this process bear large amount of heat which can be extracted and used for various purposes. In this project an attempt has been made to harvest this biomass energy in its initial stages and use it for the purpose of heating water on a daily basis.

Background

Charles Browne, the Chief of Chemical and Technological Research Bureau of Chemistry and Soils, in 1933, in one of his observations related to storage of agricultural products stated that materials like hay, cattle feed and cattle dung undergo heating process, the rise of temperature upto a point where spontaneous ignition is produced. He saw evidence of volatile hot pockets within the heaps which reacted with oxygen from external air.

Jean pain in 1970's invented the compost heater, a compost-based bioenergy system that produced 100% of his energy needs. He could heat water up to 60°C at a rate of 4 litres/min which was used for washing and heating. He also distilled enough methane that could run an electricity generator, cooking elements and power his truck. This method later came to be known as "Jean Pain Composting". Since then it has become well known that microbial activity can raise the temperature of compost to as high as 65°C.

This concept could be used in Indian context for cow dung as it is available in ample amount. Later with research, it is possible to extend it to urban and industrial waste.

Experimental Investigation

The experiment was carried out at Govardhan Kendra, Dehu, Pune. Cow dung was collected and placed in a pile of dimension 2.2m x 2.0m and height 1.7m. temperature in the pile was recorded at different depths along the centre of pile using a digital thermometer (Model Mextech DT-9; Range: -50 to 300 °C). Table represents the observations that were recorded during different times of the day for a pile of Cowdung.

This helped to understand the incremental increase of the temperature in the pile. The observations have been exclusively taken during the 3 discrete stages of the day while there is significant variation in the atmospheric temperature.

Eventually, the observations indicate that the central portion of the compost recorded the highest temperatures and temperature goes on decreasing as we move towards the outer surface. This helped in identifying maximum temperature points for placement of the heat exchanger. Also, literature review highlighted that maximum temperature is possible at a distance of 15 to 30cm from the outer pile surface.

Table 1: Temperature observations for pile at Dehu

Time of observation	9am			1pm			5pm		
Stay period 8/7/18 to 14/7/18	0.5m	1.0m	1.5m	0.5m	1.0m	1.5m	0.5m	1.0m	1.5m
15/7/18	29.2	31.2	31.0	32.3	33.0	33.1	31.4	32.6	32.5
16/7/18	29.3	31.2	31.2	33.0	34.5	34.2	33.1	33.9	33.6
17/7/18	32.0	34.9	32.6	34.5	37.3	35.8	34.0	34.9	35
18/7/18	31.8	34.6	33.5	344	41.2	39.0	34.6	37.1	36.5
19/7/18	31.0	34.9	33.8	35.2	44.0	41.6	34.9	41.5	40.1
20/7/18	31.9	36.4	35.2	35.5	47.2	47.0	34.9	44.4	44.5
21/7/18	31.8	38.5	35.3	35.2	47.1	46.9	34.8	45.0	44.8

Methodology

From the experimental investigation and literature review, it is fully justified that composting has high potential to be used as a source of renewable energy. The primary objectives of this study were:

i. To identify the potential of energy generation from Cowdung through composting.
ii. To develop technological solutions for harnessing this energy.
iii. To identify optimum use of this harnessed energy especially in rural areas.
iv. To evaluate its feasibility by comparing it with performance of alternative energy resources.

The principle of geothermal heat systems can be used to recover heat from the compost systems also. Geothermal systems consist of a heat exchanger and a heat pump. The exchanger can be in form of a piping system or any water body or borehole. From the heating perspective, compost heat recovery systems offer more efficiency over conventional geothermal systems because temperature is much higher in compost piles as they generate heat themselves unlike geothermal thermal systems that rely on heat from sun to raise the ground temperature.

Heat recovery in composting systems can be done in following two ways:

i. Direct recovery system
ii. Indirect recovery system

Direct recovery system

In direct method heat is extracted from the material during composting. It can be done in two ways:

a) Water heating: This method involves circulating pipes through the piles of composting material. This is a simple and effective method invented by Jean Pain. This method is suitable for use at personal level as it is time consuming and requires labour because the process involves piling up, installation and removal of pipes. This is not feasible at commercial level due to its time and labour requirements.

b) Space heating: In this method heat is pulled out or pushed through the composting system to heat up a space through a complex mechanical arrangement. This method is generally used in horticulture for maintaining ambient soil temperatures as per requirement of the plantations.

Indirect recovery system

This method involves indirect extraction of heat by altering the form of biomass itself. It is an advanced compost and energy system (ACES) which involves evaporating the feedstock using well fed microorganisms that produce heat above 80°C. This system does not require any additional energy.

This study focuses on direct recovery system through water heating. Initially a preliminary experiment was conducted to obtain the range of temperature and heat distribution through the pile. Based on this observations, geometry of the system was decided.

Setup design

After identifying the maximum heating points in the Cowdung pile and accompanied by the results from literature review, it was observed that maximum temperature in the pile was recorded at a depth of 15 to 30 cm from the surface of the pile. According, the heat exchanger had to be placed inside the pile with an offset of 40 cm from the outer surface. The exchanger was elevated from the ground level by placing it on three tyres so as to achieve the bottom offset and securing it for a firm stand. The purpose of selecting tyre for this purpose was that it has an extremely slow rate of decomposition. Selection of any other material would add up the need of studying the reaction of Cowdung on that material over a period of time. After firmly placing the heat exchanger on the tyres it was covered with Cowdung from all other sides, forming a pyramidal shape at the end. Extensions for plumbing were left carefully during the piling process for the inlet and outlet of water from the cylinder after it gets heated. Valves are provided to control the inflow and outflow of water manually through the system. An extra control valve is provided to know the full condition of cylinder.

Execution and Observations

Site description: The site is located in Chinchwad at Kendriya Goshala. The premise is owned by Mr. Gawade. The site is used as a caretaking place for cows to promote their importance and spirituality in Indian culture. This site was chosen as Cowdung was available on site which avoided the need of material transportation. Moreover, the condition seems practicable considering the area of application as rural. It was also possible to test the applicability of project with the help of the caretaking family that lived there.

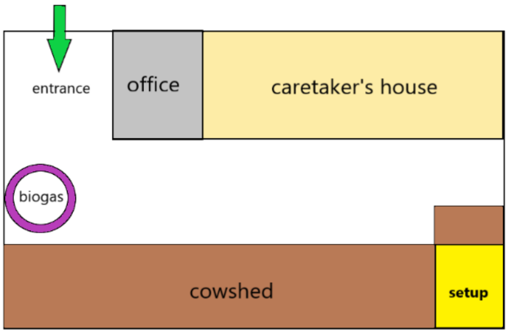

Figure 2: Site layout

Construction and Operation: Initially the ground was cleared and levelled properly in order to ease the assembly of setup. Three rubber tyres were placed at the approximate centre of the plot (1.22m x 2.5m x 1.22 m). The heat exchanger was places on these tyres so as to maintain the offset requirements from the bottom. The inner portion of tyres was filled with bricks and Cowdung to maintain its stability. After placing the cylinder, pipe fittings for inlet, outlet and control valves were done. Then this entire assembly was covered using Cowdung keeping enough thickness around the heat exchanger. The pile was loaded to form a pyramidal pattern at the end.

Once the setup is complete, a minimum 7 days stay period is to be provided for the initial settlement and start of heating action. The outer layer of Cowdung dries and hardens up forming an insulation layer that prevents the escape of heat from the pile. Then the tank can be filled through the inlet pipe. Once the tank is filled completely, the heating process starts. The heated water can be removed using the outlet pipe as per requirement.

On-site hot water demands: The average value for daily hot water consumption for the family at the site was calculated as 90 L d^{-1} (including cold water mixed). 5 gallons water at 50°F and 15 gallons water at 120°F mixed together gives 20 gallons water at 102°F. The tank capacity was 50 L i.e. approximately 14 gallons. Hence the family has an access to 14 gallons of hot water at temperature 125°F to 135°F. This would make them available with 25 gallons of water that would sufficiently fulfil their bathing requirements.

Energy collection and utilization: A heat exchanger was designed for the collection of energy generated during composting. The heat exchanger selected for the purpose of this study was a cylinder made of stainless steel that was placed in the Cowdung pile. In this case, the cylinder that was used was the one that is used in solar water heaters. The insulation was removed and bare cylinder of capacity 50 L was used as a heat exchanger. The cylinder was fitted with inlet and outlet pipes as shown in fig.3.

Figure 3: Heat exchanger used in the setup

Figure 4: Actual setup at Goshala

Energy extraction is done by transferring the heat from Cowdung pile to water inside the cylinder. Once the cylinder is filled with water, it starts heating by the heat from the pile. This heated water can then be removed from the outlet pipe and can be used further. The family at the site uses this water for bathing purpose once in a day.

Results and Discussion

Table 2 shows the temperature recorded of water at the outlet during different time intervals.

Table 2: Recorded water temperature

Time when recorded	Temperature °C
8 am (8/2/19)	26.5
10 am	32.6
12 pm	34.6
2 pm	36.0
4 pm	39.3
6 pm	40.3
8 pm	43.8
10 pm	44.9
12 am	46.1
2 am	47.9
4 am	48.6
6 am	49.3
8 am (9/2/19)	51.9

Cost Benefit Analysis: This system proves out to be highly efficient in terms of the economics as compared to the household solar water heater and electrical water heater. The table 3 indicates the cost comparison of this heater with respect to the other heaters.

The observations made with respect to solar water heater in the table above are as follows

1. The fixed capital of the solar water heater which includes purchase and installation is almost 6 times costlier as compared to cow dung powered heater
2. However, since solar water heater doesn't not incur any electricity bill and the only the maintenance cost is incurred as working capital, it turns out to be slightly cheaper as compared to this setup.
3. The capacity of the solar water heater also surpasses the capacity of the standard size of this setup by a large margin. However, that can equalize by increasing the size of the tank.
4. However, in the long run, solar water heater become inconsistent due to weather changes whereas this water heater can deliver consistent results.

Table 3: Cost comparison of different water heating systems

Type of water heater	Household solar water heater	Electrical water heater(non-instant)	Cowdung powered water heater
Fixed capital	20,000/-	3000/-	3200/-
Working capital	100/month	600/month	150/month
Capacity	100-300 litres	5 litres	50 litres
Consistency glitches	Less during cloudy days and night time	Cannot function during power cuts	Needs 24hrs time to heat up if evacuated fully

The observations made with respect to electrical water heater is as follows:

1. Firstly, the fixed capital of the electrical water heater only involves the purchase cost and the cost doesn't differ significantly with respect to this setup. However, the setup is tedious to install and requires manual labor work which is easier in the villages and is not suited for the cities whereas the electrical water heater requires only plug in and switch on which can be used my people both in villages in cities
2. Secondly, the working capital of this setup is 4 times less as compared the electrical water heater. this is mainly because the electrical water heater will generate electricity bills and this heater does not incur any bill-based cost.
3. Thirdly, the capacity of this setup is 10 times more as compared to the highest capacity of a conventional electrical water heater. this makes this setup deliver higher volumes of hot water at one go and reduces the wait time.

Lastly, the electrical water heaters are fully dependent on power supply and cannot be run on inverters too. Hence, the power cut will result into redundancy of the electrical water heater. Therefore, electrical water heater might not be of much use in villages where power cuts are consistent. Hence, Cowdung powered heater acquires an upper hand because it is independent of any power supply and can function endlessly throughout its span.

From this it is clear that reusing the heat offered by the Cowdung is an economically attractive option when compared to alternate possible renewable sources. It is able to provide the highest proportion of the total hot water requirement of the three systems. The capital cost of using the heat from the compost, although large, is also attractive when compared to its competitors.

Conclusion

Therefore, the conclusions drawn from economic comparison of this setup, electrical water heater and solar water heater are as follows:

1. Fixed capital of this setup is best suited for villages which have power cuts and have the manpower to carry out the tedious task of setting up the setup
2. It doesn't not incur any electricity bill and the resources need to maintain the Goenergy setup that involves mason tools and cow dung are readily available in the villages
3. The capacity of this setup is appropriate as it is neither to much to occupy huge nor to less to give insignificant output. Hence it can we readily used with the standard measurements.
4. The consistency of the setup is the most viable factor that proves it to be better suited to the villager's requirements.

The product that could be developed out of this project will fit in aptly in the rural Indian's life as a valuable source of energy helping him be independent of the government rules, regulations, procedures and inflating cost of the energy.

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