# STUDY OF HOUSEHOLD BIODIGESTERS

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**ABSTRACT**

*Tunnel or tubular type of bio-digester has been widely developed in many countries for producing a renewable clean fuel gas named biogas. This digester type only requires minimum maintenance and simple construction for ensuring its lower cost compared to others with similar capacity. Mostly, polyethylene (PE) plastic bag is used for construction materials of the tubular digesters. In this research, the tubular type has been constructed using large diameter PVC (Poly Vinyl Chloride) pipe for increasing the durability and safety. The performance of PVC digesters have been tested by measuring biogas production rate and $CH_4$ concentration in the gas. COD (Chemical Oxygen Demand) and BOD (Biological Oxygen Demand) drop between inlet and outlet sludge have been measured for examining the digester efficiency. Then, the performance was compared with PE plastic digesters data from several literatures which still needs some improvements for enhancing its capability and performance.*

**Keywords**: *Tunnel digesters, manure, fertilizer, biogas, COD, BOD*

## INTRODUCTION

Many people harm their environment whereas at the same time they risk their own lives. Poverty is regarded as the sustainable development main barrier due to its tendency in direct extraction of natural resources for fulfilling the basic needs (World Commission on Environmental and Development, 1987). For instance, many households in Indonesian villages use open indoor wood fire pits for cooking and light. Chronic exposure to poor indoor air has been linked to acute lower respiratory infection which is the leading cause of death in children under the age of five. Tuberculosis and low birth weight have also been implicated as consequences of poor indoor air. Moreover, many hours per household per day has spent for looking and gathering firewood which is mostly done by the females in families.

Above unfavorable condition can be avoided if local resources can be utilized optimally and sustainably by appropriate technology for supporting the poor. Narrowing to the energy sector for rural people, actually there are many sources of renewable energy that until now are still inadequately utilized. If a simple technology can be introduced to the people to produce energy from their own local materials, their economy as well as health conditions will improve. One of the potential raw materials for producing energy which is mostly available in rural area is animal excrement (manure).

Manure is an important source of fuel in many Asian cultures. It is estimated that 8% to 12% of the world's population depend on manure for heating and cooking (Ramachandra, 1994). Animal manure is a valuable fertilizer as well, conferring inputs to the soil over and above the simple chemical nutrients of Nitrogen, Phosphorus and Potassium. One way to improve a better utilization of manure is undoubtedly through biogas production that can be a center of integrated farming practices (Preston and Rodríguez, 1998). Integrated farming system, that is, a system that combines preserving the environment; protecting the health of farmers, their families, neighbors and consumers; providing a decent income and a high quality of life for farm families; sustaining vigorous rural communities; and producing plentiful, nutritious, affordable food.

Biogas is considered one of the cheapest renewable energies in rural areas of developing countries. Biogas is a sustainable energy source and would decrease the environmental damage related to the over-use of forested land and watersheds. Nowadays, as sources of fuel-wood become scarcer, steep hillsides are being cut, resulting in an increase topsoil losses, danger of landslides, silting of streams and rivers and a decrease in reforestation. On the other hand, many villages in Indonesia, range cattle freely. Villagers and their water supplies are exposed to pathogens found in animal feces. Constructing household bio-digesters would require that livestock be penned so that the manure can be fed to the

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inlet pipe. Using bio-digesters prevents the survival of most pathogenic organisms. Effluent has a decrease in chemical oxygen demand (COD). There is more than a 99% cut in *E. Coli* concentration. Families with bio-digesters report fewer insects, cleaner water and a cleaner environment (An et al., 1996). Many developing countries, such as Colombia, Ethiopia, Tanzania, Vietnam, Cambodia, promoted the low cost bio-digester technology aiming at reducing the production cost by using local materials and simplifying its installation and operation as described in Figure 1.

Plastic biodigester (Figure 1) in several occasions have been introduced to people in Piyungan, Bantul, Yogyakarta, however they were reluctant to accept this kind of digesters due to low durability and unpleasant outlook. Thus the authors were trying to replace the material with sturdier one yet affordable. The improvement of biodigester is by replacing polyester plastic with large PVC pipes. The new material will enhance the durability and safety of the digester (Purnomo and Pertiwiningrum, 2008). After replacing the construction material, the performance of new digesters is measured, compared and optimized. In here, the optimum condition operations have been sought to be used as guidance for digester owners (Standard Operating Procedures).

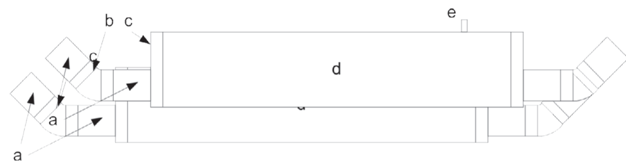

Figure 1. A low-cost digester made of polyester tube in Vietnam as an option (Bui Xuan An and Preston, 1995)

## MATERIALS AND METHODS

In Figure 2, the diagram of digester using PVC pipe is shown. The length of 12 in pipe is commercially standardized at 4 meters. The volume of one digester using 4 meters PVC 12 in diameter is about 250 L. If the digester filled with manure about 80% it is expected that one pipe length of 12 in PVC can produce 0.5 $m^3$ of biogas daily which can fired a stove about 1 hour. The manure needed for 4 meter length of PVC digester is only one adult cow. Thus, this model of biogas is easily adjusted with the number of animal (cow or buffalo) owned by the local people. The arrangement of pipes is in series or parallel depends on the available land area and the number of raised cattle. The digester can be place above ground or underground, however for ensuring temperature stability half buried digester construction is recommended.

a. PVC pipe 2 in b. elbow $45^0$ 2 in c. Plug 12 in (drilled)
d. PVC pipe 12 in e. PVC pipe ½ in (gas outlet)

A




B

Figure 2. A. PVC digester assembly and its components; B. installed PVC digester in Piyungan Bantul, Yogyakarta.

The length of bio-digesters can be adjusted by assembling 2 pipes of PVC pipe 12 in. Thus, the maximum length becomes 8 meters because each of commercial pipes has a standard length of 4 m. The length of digester is suggested up to 8 meters to preserve its portability and low cost characteristic. The retention time of manure should be adjusted by changing feed rate of fresh manure to get optimum performance for different length of digesters.

In here, the digesters' performance has been measured by several categories. This measurement aimed to ensure the digester operation and to be compared with conventional PE digesters. Several parameters have been analyzed for measuring the new digesters performance. The data is collected from more than 10 digesters installed in Piyungan, Yogyakarta Region. The measured parameter is listed below.

1. Biogas Production Rate

   This parameter was measured by examining the volume of biogas produced in a day during a week in operation. The gas from each digester is collected in expandable plastic gas storage so that it was easy to measure the daily volume of produced gas. The volumetric data of biogas in a week then averaged and stated in $m^3$/day.

2. COD and BOD
   Inlet and outlet slurry of the digesters were sampled and analyzed for COD and BOD level. The difference of COD/BOD value between inlet and outlet can be used for determining digester efficiency. The COD and BOD drops are stated in percentages.
3. Methane concentration
   The produced biogas was daily sampled within a week and tested for its methane content. The measurement was using Gas Chromatography. The concentration is stated in volumetric percentages in standard temperature and pressure (STP).
4. Residence time (retention time)
   Residence time represents the time duration of the slurry being processed inside the digester. This parameter can be easily calculated by equation (1).

$$R = V/F \qquad (1)$$

where, R = residence time (day)
V = volume of digester (L)
F = daily feed rate (L/day)

Several operation variables have been varied and measured the effects in each of the above parameters. The variables are length of digesters and manure water ratio.

## RESULTS AND DISCUSSION

The summary of all variable effect on digester performance is represented in the Table 1 below.

### Length of Digester

The length of digester has been varied for investigating the length effect on gas production rate. Several digester with different in length from 4 m up to 8 m is regularly fed by the same amount (15 liters per day) and concentration of manure slurry. The length of pipe will determine the residence time of manure inside the digesters. This variation aimed to obtain the optimum residence time of the slurry that can be translated to the optimum length of digesters.

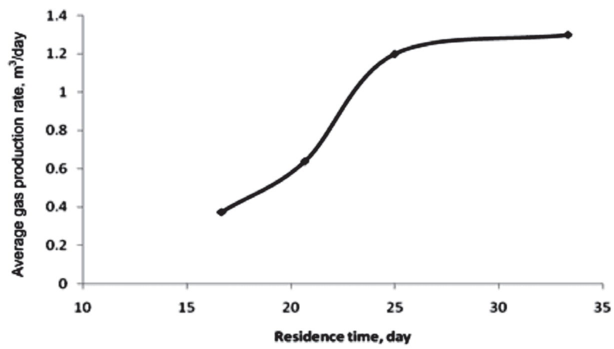



Figure 3. The graph of the digester length versus gas production rate

It can be seen from the result that has been shown in Figure 3. for the first 25 days, the longer the residence time, the larger daily production of biogas. Therefore, after 25 days of residence time, the increase of gas production rate is not significant. It is suggested that the optimum length of the digester is 6 meters (25 days of residence time) for 15 liters/day of feed which can be fulfilled by one cow only.

### Manure and Water Ratio

The water for diluting manure was varied. The smallest ratio that has been applied was 1:1 of manure and water and the larger ratio was 1:4. From the Figure 4, the optimum ratio is 1:2 or the fresh water is making up of 66% of the digester

Table 1. The results of several variations in digester dimension and operation conditions

| No | Digester length (m) | Manure- water ratio | $CH_4$ concentration (%) | Biogas production rate ($m^3$/day) | Cooking time (hour) |
|---|---|---|---|---|---|
| 1 | 4 | 1:2 | 37.41 | 0.38 | 0.70 |
| 2 | 5 | 1:2 | 37.24 | 0.64 | 1.19 |
| 3 | 6 | 1:2 | 38.15 | 1.20 | 2.23 |
| 4 | 8 | 1:2 | 38.20 | 1.30 | 2.42 |
| 5 | 4 | 1:1 | 37.32 | 0.29 | 0.55 |
| 6 | 4 | 1:3 | 37.44 | 0.24 | 0.45 |
| 7 | 4 | 1:4 | 37.52 | 0.21 | 0.41 |

feed. If the fresh water is insufficient, the produced gas will be reduced. The reason could be that the high concentrated organic feed is quite hard to be digested by the microorganism inside the digester. On the other side, for highly diluted feed might cause insufficient concentration organic matter for sustaining the microorganism growth.

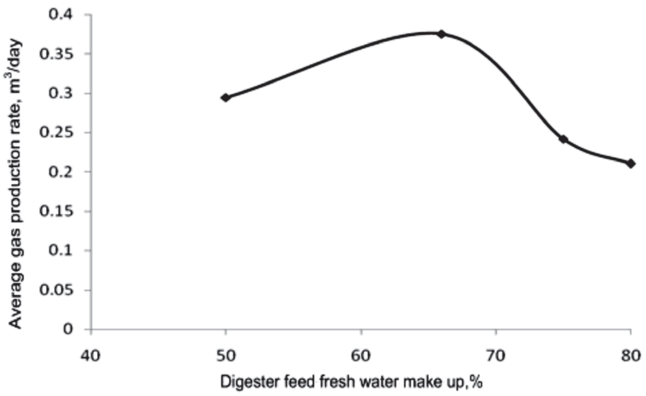



Figure 4. The concentration of fresh water effect over biogas production

## BOD AND COD DECREASE

The length of digester and the ratio of manure and fresh water effect on BOD and COD drop between inlet and outlet sludge have been observed. In general the longer digester and the larger portion of fresh water will increase the COD and BOD drop percentage as shown in Figure 5 and 6. In Figure 6, it can be said that larger portion of water will have larger COD and BOD decrease. Meanwhile, Figure 4 shows that larger portion of water will result in smaller gas production rate. This phenomenon can be explained by considering that more dilute manure has smaller substrate to be processed to produce gas in the same feed rate. On the other hand, adding larger portion of water in the feed will enhance the digestion capability of microorganism causing larger difference of COD level between inlet feed and effluent. Moreover, the

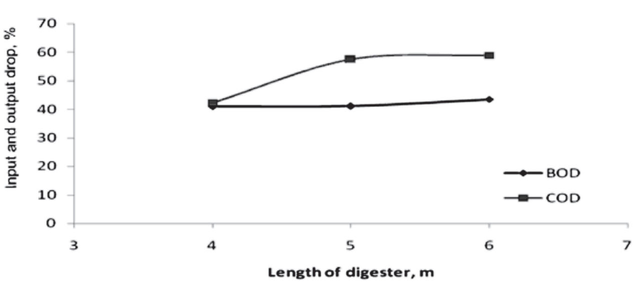



Figure 5. COD and BOD decrease by variying the length of digester

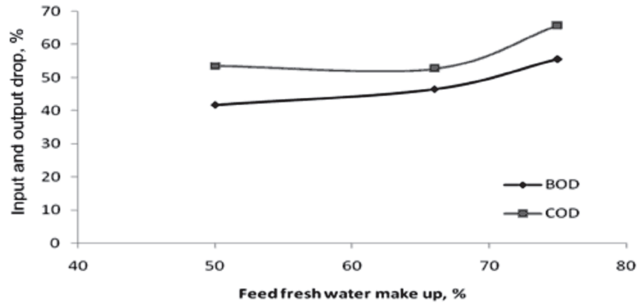



Figure 6. COD and BOD decrease by variying water make up

dilution process itself without microorganism assistance can also reduce COD level.

However, the decrease never reached above 70%, which might represent low digester efficiency. This low performance might be due to washing out mechanism of some untreated manure inside the digester. This situation is possible because the digester construction is only a hollow pipe which has no difficulty for undigested manure to flow out in a short retention time. For improving the condition, several digester modifications will be pursued such as adding packing structure inside the digester pipe as flow regulator and microorganism growth medium. The other method for improving digesters efficiency is attaching mixing device inside the PVC digesters for ensuring homogenity and breaking hard crust (scum) above the slury that can hinder biogas bubles flows.

### Biogas Concentration

The $CH_4$ concentration has been measured as well for evaluating the performance of digester. In this experiment, the concentration of $CH_4$ inside the produced gas is sufficient as gas fuel but the concentration have never reached above 50%. Similar as the discussion in COD and BOD decrease above , the digester still need some improvements so that the $CH_4$ concentration will be enhanced. One of possible improvements that can be further observed is addition of starter (effective microorganism) to enhance microorganism population for better gas production and COD digestion. Table 1 above sumarizes the results of concentration measurements of digester's outlet which are able to reveal that the length and water manure ratio variations would not much affect the concentration in the produced biogas.

### The Performance Comparison

Several main parameters in average of PVC digesters above will be compared with PE digesters in a previous report (An, 1997) and summarized in the Table 2 below.

Table 2. Digester performance comparison

| Parameters in average | PE | PVC |
|---|---|---|
| COD removal /digester efficiency (%) | 62 | 55 |
| $CH_4$ concentration (%) | 56 | 38 |
| Digester Volume (liter) | 5,100 | 250 |
| Cooking time (hour per day) | 4.4 | 2.0 |
| Expected digester life time (year) | 2 | >10 |

From the above data, almost all the performance parameters of PVC digester are below the PE digester. However, the higher values of PE digester mainly due to larger volume which requires larger site area for installing the digesters. By the large average in volume of PE digester type with cooking time about 4 hours, it can be said that the digesters is not effective in processing the manure. On the other hand, by only about 1/20 of PE volume, PVC digester can produce biogas for 2 hours cooking or a half of PE digesters cooking time. It is also reported that about 30% of PE digesters were failed in operation due to leakage and other technical reasons (An, 1997). The short life time of plastic digesters is also another drawback of this type. For installed PVC digesters, all the units can produce biogas successfully even though the installation cost is around 4 times more expensive than the plastic digesters.

## CONCLUSION

From this experiment, the optimum operating procedures for a new type of digesters have been obtained. The optimum residence time for the PVC digester is suggested at 25 days with the manure and water ratio at 1:2. The developed PVC digester still needs some improvements for enhancing its capability and performance.

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