

*Review Article*

## Portable Bio-digester System for Household Use — A Review

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**Abstract:** Biogas is a value-added product comes from anaerobic digestion of organic compounds. The most common biogas production is done in large capacity, which requires large area and high cost to be operated. In order to benefit the consumer on biogas production, varieties of innovated household bio-digester machines were introduced. This portable household bio-digester appeals to the rural to provide an economical and alternate source of energy apart reducing the organic waste dumping to landfill. Biogas produce consists of methane gas, which can act as an alternative for cooking gas at home. In the meantime, effluent obtained at the end of anaerobic digestion can be used as fertilizer. Moreover, the cost of production is cheaper and easier to be operated. The size of portable household bio-digesters varies in the range of 1 to 150 m<sup>3</sup> with common designs such as fixed dome, floating drum, low-cost polyethylene tube, plug flow type and balloon type. Fixed dome is not costly to be built, however, the gas pressure fluctuates substantially depends on the invisible volume of biogas stored. Floating drum is more efficient as it provides larger space for biogas storage, but it is costlier compared to the fixed-dome due to its complex design. For low-cost polyethylene tube, it is much simpler than fixed-dome and floating drum, which indirectly reduce the cost, while has its limitation on life span due to its simpler design. Next, plug flow design has no moving parts, which reduces risks for failure, while on the other hand, it needed biogas storage, since it cannot store sufficient amount of biogas. The fifth design is balloon type that is commonly using reinforced plastic or synthetic caoutchouc as the main material of construction that is resistant to extreme weather and UV, but it has higher potential of leakage. This review paper aims to bring a further understanding of existing designs, capabilities and limitations from different types of household bio-digester that have been used.

**Keywords:** Biodigester, biogas digestion, household, solid waste, food waste

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## 1. Introduction

Municipal Solid Waste (MSW) is defined as waste or refuse from households, hazardous solid waste from industrial and commercial establishments, refuse from institutions, market waste, yard waste and street sweeping (Council *et al.*, 2008). Every day with the expansion population and economic activity, a huge amount of MSW is being produced and dumped. The accumulation of food waste is one of the burdens to society and municipalities all over the world. This attitude of dumping food waste together with the other unwanted solid waste is a big loss, in terms of negative influences on environmental, health and also economical. Among the solid waste, 45% is the food waste, which their benefits in saving a sick world has been ignored by mankind all around the world. Data analyzed from residual household waste collected from 1474 households exhibited that  $183 \pm 10$  kg per year was food waste (Edjabou *et al.*, 2016).

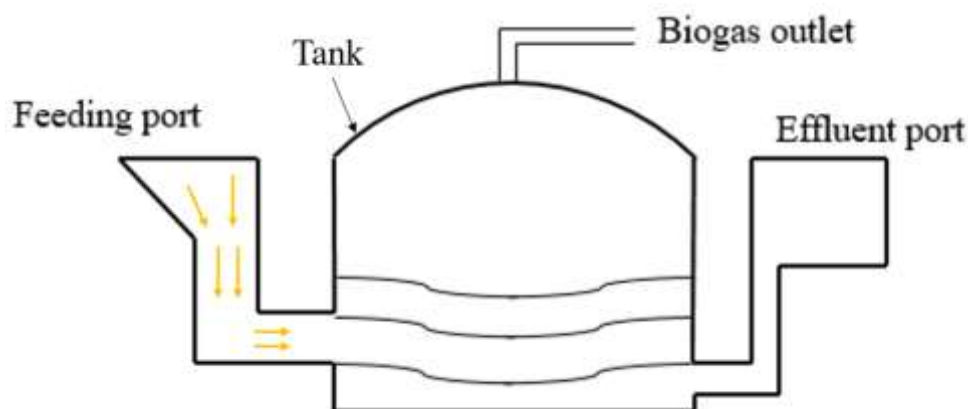
Anaerobic digestion (AD) is seen to be one of the most convincing technology to generate renewable energy from organic matter and produce bio-fertilizer for agriculture sector (Nguyen *et al.*, 2014). AD is a complex biochemical reaction that combines chemical and physico-chemical reactions in four stages before biogas is produced. This reaction involves specific microbial species to treat the organic matter and produces renewable energy from the biogas production (Zhao *et al.*, 2019). Capturing and storing biogas are important parameters that need to be focused in contributing to methane emission reduction and as a renewable energy source (Atalge *et al.*, 2018).

AD usually needs a specific environment, where there is no presence of oxygen and needs a specific temperature to react. A reactor system known as a bio-digester or biogas digester is being developed to fulfill the requirement of AD. To be specific, bio-digester is a machine or system, in which the digestion of organic waste matter by the bacteria culture takes place while producing biogas and a nutrient-rich by-product (Merriam-Webster.com Dictionary, n.d.). Many designs have been developed nowadays to make sure our environment is cleaner and safer for the young generation, apart from getting benefits from the biogas produced. Every design has advantages and disadvantages. A portable bio-digester is one of the promising designs that can be used as a household bio-digester. According to Cambridge dictionary (n.d.), portable means possible to take with or move to a different place, while Vocabulary (n.d.) describes the word as "to carry", which means something you can carry. Thus, a portable biodigester is designed to be moved from a place to another, which is more convenient to be used for the household. But, the limitation of a portable bio-digester is it can only produce a small amount of biogas compared to industrial bio-digester.

In this study, various designs and systems were reviewed to discuss and distinguish the advantages and disadvantages of each portable bio-digester system for the anaerobic digestion process.

## 2. Fixed-dome

The fixed dome bio-digester, also known as “Chinese” or “hydraulic” digester is the most common design developed and applied in China for the biogas production (Santerre & Smith, 1982). It is called fixed-dome because of its upper part (dome) is built-in together with the body part, which cannot be moved or separated. The dome is mostly made of granite, sharp sand, iron rods, and cement. Some of the essential consideration of design includes local climate, volume of waste and volume of water required for everyday input into the anaerobic digester. The bottom part of the digester includes a bio-solid layer, and a liquid layer above the bio-solids (Uche *et al.*, 2020). Fixed-dome plant has an inlet chamber feeding into the digester, which is topped by a dome expansion chamber with a gas release point to discharge biogas produce. A slurry outlet from the digester can feed into a tank, providing high-quality fertiliser. The organic matter feeds into the main tank through the feeding port as shown by the direction of arrows in Figure 1. Then, biogas produce is transferred into the gas storage through the upper part of the main tank. An effluent port is collecting liquid, which can be used as liquid fertilizer. Figure 1 shows how the system works.



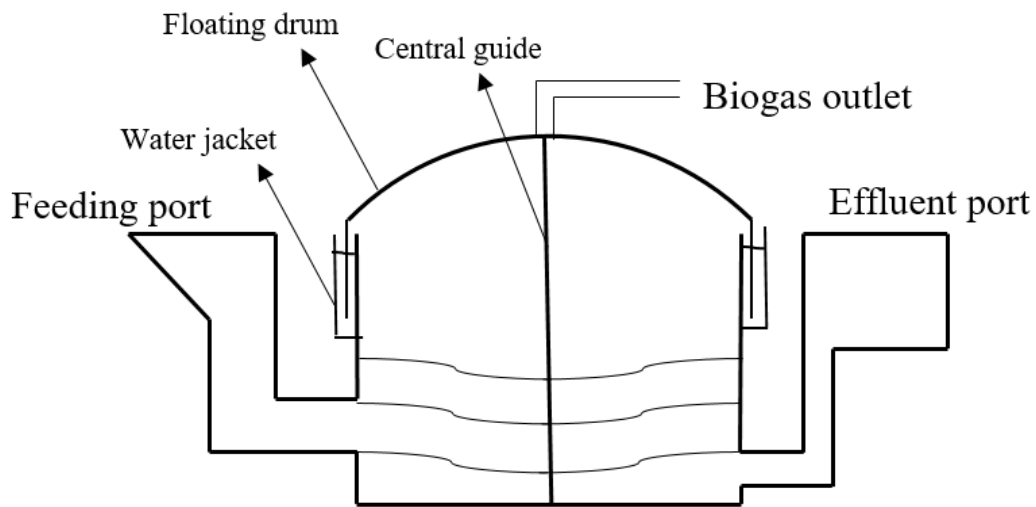
**Figure 1.** Sketch of fixed-dome bio-digester (Rajendran *et al.*, 2012).

This design usually uses plastic-based material to avoid the material rust or reacting with the organic matter. Thus, it is lower in cost to be built due to the type of material used and simple design. Moreover, the fixed dome design on the upper part helps it to lengthen the operational life of this bio-digester as it has no moving parts for gas utilization. The risk of cracking and porosity due to the hydrostatic pressure between the lower and upper part of the dome can be reduced by using special sealants with gas-tight properties. However, this fixed-dome bio-digester is less effective as the gas pressure will fluctuate substantially depends on the invisible volume of biogas stored and this design also lack of agitation action that causing slower anaerobic digestion reaction, which directly effect on amount of biogas

produce. This observation was made in a laboratory experiment the biomass was detected in a digester bottle, whereby water particles get separated after some time and created two unusual layers. The biogas was trapped in the layer of biomass, which resulted in a non-uniformed mass transfer of biogas in the digester. The agitation can help in proper mass transfer by uniform distribution of mixture inside the digester. It facilitated in uniform distribution of temperature (Kaur & Kumar, 2017).

### 3. Floating Drum

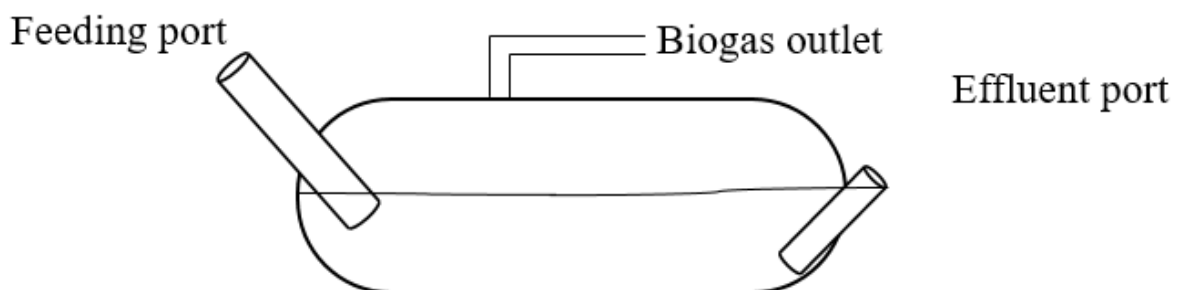
Khadi and Village Industries Commission (KVIC) is the name for floating drum biogas digester design which was developed in 1962 (Figure 2). Even though the design is quite old, it is still acceptable and used in the Indian community until this new era (Ishmael *et al.*, 2014). Floating drum digester is an innovation design from the fixed-dome biogas digester. The fermentation chamber acts as the holder unit for gas in this system, known as a gas holder. A gas holder provides more spaces to store a certain amount of biogas with constant pressure. For this design, mild steel is commonly used to create the gas holder, thereby making it less costly and not prone to corrosion. The fixed dome type could last longer than the floating drum (Nkoi *et al.*, 2018). The volume of stored biogas is visible directly as the drum rises when biogas collected and moves down when it is consumed. The floating gas holder floats in the water-jacket when the slurry is being fermented, to provide more aesthetic appearance and prevent substrate from being trapped especially with high solid content. Painting floating drum in dark color may help in the higher biogas production due to the high temperature increased by solar radiation and absorption of heat. This is because high temperature improves the bacterial action on organic materials, which also helps to reduce the chemical oxygen demand (COD) of waste to be used as fertilizer. A central guide constructed inside the biogas digester is to prevent the floating drum from tilting, when a maximum amount of biogas stored. At the beginning of operation, air trapped in gas holder was eliminated to minimize the risk of explosion. The air if allowed, aids combination of methane and oxygen, which is an explosive mixture and can cause serious hazards when accidentally exposed to spark or fire (Ononogbo, 2015). The main system works similar to the fixed-dome biogas digester design but more efficient as it provides larger space for biogas storage. One of the recognized disadvantages of this design is it is costlier compared to the fixed-dome type.



**Figure 2** Sketch of the floating drum biogas digester (Rajendran *et al.*, 2012).

#### 4. Low-Cost Polyethylene Tube Bio-digester

Low-Cost Polyethylene Tube Bio-digester was applied in Bolivia (Peru, Ecuador, Colombia, Centro America and Mexico). The tubular polyethylene film was bent at each end around a 6-inch PVC drainpipe and wounded with rubber strap of recycled tire-tubes. With this design, an air tight tank is obtained to provide a system for anaerobic digestion. The amount of biogas produced was to a large extent dependent on the outside temperature and placing the digesters in a non-shaded area. It is possible for using a transparent material, but be sure to cover the tube with a non-transparent material or to build a roof over the digester in order to avoid algae formation due to direct sun exposure (Eckerwall *et al.*, 2015). In general, this design is much simpler to construct compared to fixed-dome and floating drum, which indirectly reduce the cost. The system works the same as before which having feeding port, effluent port and biogas outlet as shown in Figure 3.



**Figure 3.** Sketch of low-cost polyethylene tube digester model (Ferrer *et al.*, 2011).

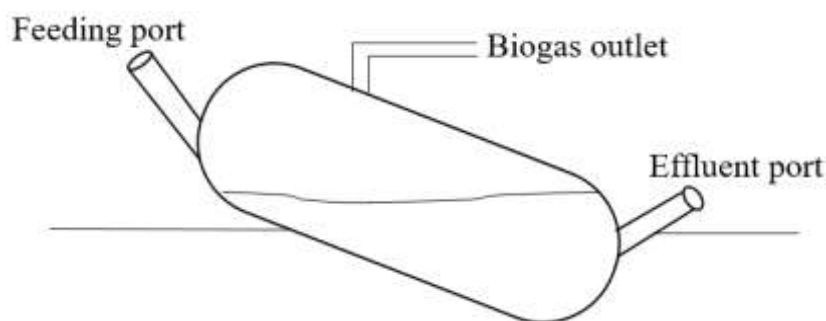
One of the 6-inch PVC drainpipes uses as the inlet of feeding and the other one as the outlet of the slurry. A hydraulic level in the tube digester is set up by the level of the effluent port. The quantity of added prime matter (feeding organic) should have the same quantity of

fertilizer leaving the outlet (EnergyPedia, 2016). Main advantages of this design is low cost, fast payback, simplicity and positive effect on pollution (An *et al.*, 1997). However, this design has a serious limitation on life span, gas pressure and gas production as it depends on the ambient temperature.

## 5. Plug Flow Bio-digesters

Plug flow bio-digesters have a constant working volume, but biogas is producing at a different pressure according to the level of reaction occur (Green & Sibisi, 2002). This design has various size range between 2.4 m<sup>3</sup> to 7.5 m<sup>3</sup>. Plug flow bio-digesters consist of a long and narrow cylindrical tank with, an average ratio of length to width 5 to 1. The feeding port and effluent port of the digester are located at opposite ends. Both inlet and outlet kept above the ground, while the main body is kept underground in an inclined position. As the organic matter is fed from the inlet, the digested matter flows towards the effluent port at the opposite end of the tank and discharged in the same volume of feed organic matter. This design was introduced to separate two processes, which are acidogenesis and methanogenesis longitudinally, therefore two-phase system produced. (Rajendran *et al.*, 2012)

The popularity of this type of bio-digester has increased lately in Peru and some other places, due to its portability and low cost (Ferrer *et al.*, 2011). Besides, some other advantages of these bio-digesters includes easy to install, easy handle, and adaptation to the extreme environment at high altitudes with low temperatures (Ferrer *et al.*, 2011). Plug flow designs are suitable for manure, and operating semi-continuously with a HRT between 20 to 30 days according to the size of the bio-digester, and solid content varying from 11 to 14%. These bio-digesters were designed with no moving parts, which reduces risks for failure (Cantrell *et al.*, 2008). On the other hand, this design requires biogas storage, since it cannot store adequate amount of biogas.



**Figure 4.** Sketch of the floating drum biogas digester (Rajendran *et al.*, 2012).

## 6. Balloon Bio-digester

A balloon bio-digester consists of a heat-sealed plastic or rubber bag, which acts like a balloon, combining digestion part and biogas storage. The biogas production from the

reaction is stored in the upper part of the balloon. The feeding port and effluent port are attached directly to the balloon main body. The inner pressure can be increased by adding external load on the balloon. If the gas pressure exceeds the limit of the balloon designed pressure, it may damage the skin of the balloon or the worst case, the balloon explodes. Therefore, safety valves are needed to be installed in the design system. Since the material used has to be resistant to extreme weather and UV, stabilized, reinforced plastic or synthetic caoutchouc is highly recommended. Other than that, RMP (red mud plastic), trevira, and butyl have been used in this balloon design. Thus, based on the material used, the cost is much cheaper than fixed dome or floating drum bio-digester. For the operating system, it is similar like previous design which having feeding port, effluent port and biogas outlet. Limitations of this design include shorter lifespan, which does not exceed 2–5 years (Hoerz *et al.*, 2008) and the anaerobic digestion in the system may be affected if leakage occurs.



**Figure 5.** Balloon digester in Costa Rica (Kumar *et al.*, 2015).

## 7. Conclusions

Several literatures pertaining to the portable bio-digester for household use have been reviewed in order to develop a better design of portable bio-digester. Every design has its own strength and weaknesses, which is being used for different purposes and depends on designer's budget. Every design has its purpose depending on the environment factor, costing and durability. Fixed dome type is cheaper compared to floating drum, but it cannot store sufficient biogas. Low-cost polyethylene tube is the cheapest among all types of bio-digesters that have been reviewed, but it has the shortest lifespan, while plug flow is more useful when it comes to extreme weather, but able to store less biogas and for the balloon bio-digester, it is proven to be resistant to extreme weather with bigger space for biogas storage, but have a shorter lifespan. The adaptation and further improvement of these bio-digesters will further improve the biogas production rate and help in saving our environment for future generation.

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