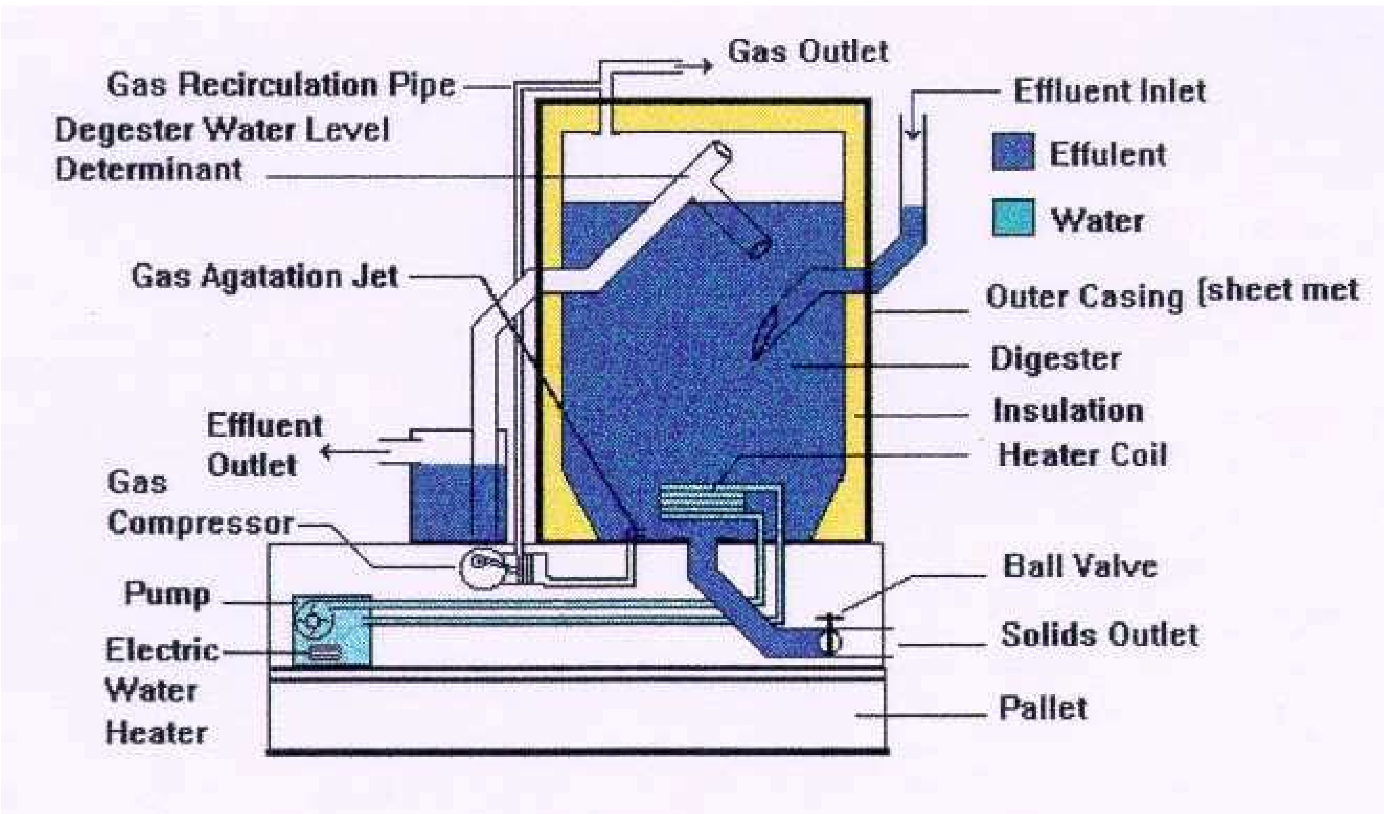
The Design and Theory of a Basic Anaerobic Digester



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Abstract

With environmental issues such as the greenhouse effect and correct waste disposal methods gaining much attention throughout the community, the concept of controlled anaerobic digestion is perhaps a much overlooked example of a way to reduce green house gas emissions and provide a better waste disposal method for organic waste.

Introduction

Controlled anaerobic digestion is by no means a radical or new concept. Large scale industrial digesters and small domestic digesters are in operation in many places around the world. The purpose of all these digesters is to produce combustible biogas which can be burned to provide energy for a whole range of uses. Here in Australia, there is quite a bit of ideological interest in anaerobic digestion and biogas production, particularly from intensive farmers, but there are not many examples of digesters in operation. These farmers are interested in this topic primarily as an alternative energy source (biogas), and secondly, as part of an efficient effluent waste disposal system for the farm. Somehow there seems to be a problem in finding ways to put controlled anaerobic digestion into practice on the average Australian farm. There is almost a small library of information from all over the world on this topic, but this information doesn't seem to be reaching the average intensive farmer with some interest in this topic. Why isn't this concept being utilized more? There could be a number of possible reasons for this including the capital cost of setting up an anaerobic digester project, a lack of working models and / or a lack of a source of ideas to base individual projects on, i.e. - trouble shooting and project development at a technical 'on farm' level. The purpose of this project was to develop a small scale working prototype possibly suited to operate on the average farm. The focus of this project was the production of usable (combustible) biogas. This project is definitely not supposed to be revolutionary or radically new, but rather to be a starting point for further research and development in this area.

The purpose of this report is not to provide a method for the fabrication of the project produced (although a basic materials list will be provided). Rather, this report will aim to identify key aspects of the design, concentrating on their function and the theory behind their function. Therefore, the aim of this report is to provide the reader with a basic explanation of the mechanics of a small, continuous flow anaerobic digester.

The Brief

The purpose of this project was to design and build an anaerobic digester to meet the following criteria.

The design should

- attempt to maximize the amount of biogas produced per unit time,
- be a continuous flow anaerobic digester. This has been specified because it seems that this will be the most practical design for continuous operation in a farm situation.
- be simple and easy to understand so that the average person is able to grasp the function and theory behind each component of the design with only a small amount of guidance. The idea here is to encourage people looking at the design to think and understand the requirements for controlled anaerobic digestion and the continuous flow model.
- be a durable, compact, versatile design which is capable of being shifted around if necessary to be displayed.
- be operated with a minimum of monitoring, regulating, and adjusting (in other words, be easy to operate).
- attempt to reduce time and money costs associated with maintenance

- attempt to minimize the cost of setting up and running the digester without compromising the performance of operation or the other specifications of the brief

- look aesthetically pleasing as another mechanism to effectively sell the concept!

Basic Summary of Materials Required

- 1 x Hardwood pallet;
- 1 x 2001t plastic drum suitable to act as a digester;
- various timber and fabricated timber supplies for the purpose of building platforms and housings for the digester and gas collection units;
- 1 x 2001t metal (44 gallon) oil drum (with bung holes as the only openings) to be used for the gas collector
- insulation
- sheet metal as a cover over the insulation
- various PVC fitting including glue, primer, various diameter pressure pipes and their associated joining fittings
- guttering silicon
- various tech screws, screws and other fasteners
- ~10m x Omm black irrigation poly pipe (to be used for heater coil and aeration line)
- 1 x 60mm ball valve fore solids outlet
- 1 x 20mm ball valve for gas outlet

Discussion of the Design

Because the gas produced in an anaerobic digester is hopefully combustible, there are safety issues to firstly be considered when designing and operating the digester. Adequate ventilation is required and be best way to ensure that the environment around the digester is well ventilated is to position the digester in an open area, preferably outdoors. This means that the digester must be weather proof. Any possible ignition sources should be kept well away from the digester. For this reason, the location of the digester on a farm should be in a low traffic area away from maintenance sheds etc.

For the purpose of this project, 1 decided that the best way to make the digester unit transportable was to build the whole unit on a pallet. From the area available on the top of the pallet, 1 formed the basic layout and determined the location of the digester and the gas collector (fig. 1).

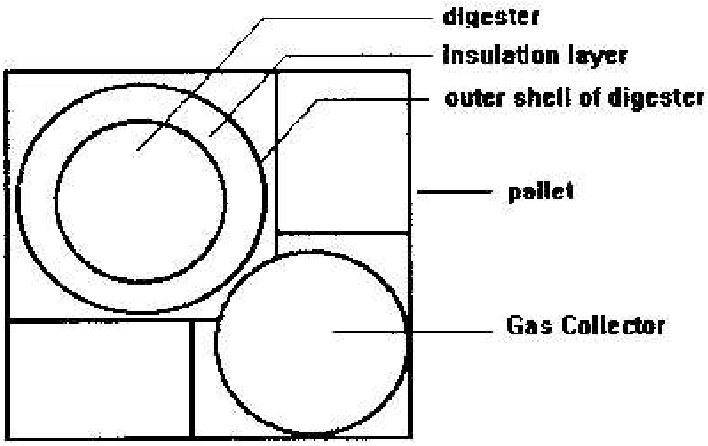

Figure 1 The basic layout of the digester and gas collector to fit on the area of a standard pallet.

The first thing 1 had to do was to build a platform for the digester to sit on. The reason why the digester had to be elevated slightly was to allow for a solids outlet pipe in the bottom of the digester (refer fig. 2). The digester was made from a 2001t plastic drum with a 'clip-on' lid, held on with a compression ring. The lid of the drum was fastened to the platform so that the drum was in an up-side down position (refer fig. 2). The up-side down position was used for a number of reasons

- to minimize the chance of gas leaks through the lid
- to enable 'easy' access to the heating coil, gas agitation jet and solids outlet in the event of an overhaul
- to provide easier assembly of the gas outlet, effluent inlet and outlet.

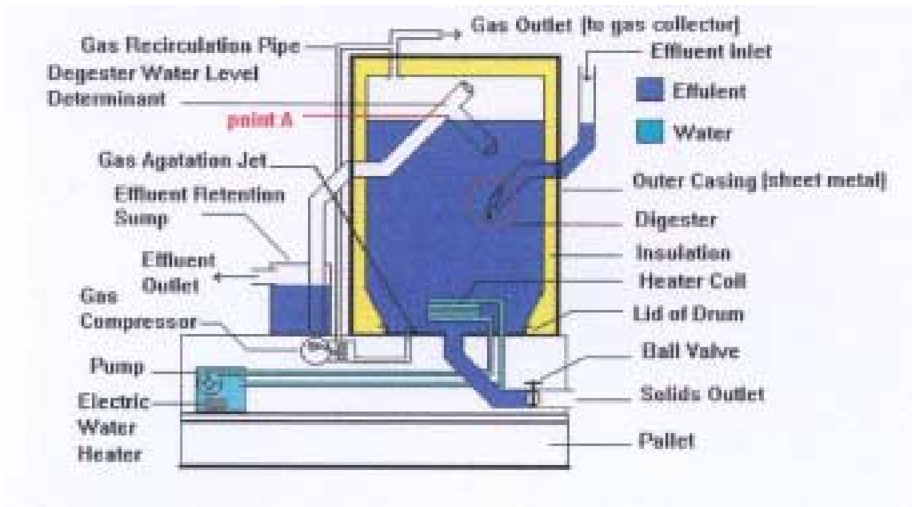

Figure 2 A diagram of the continuous flow digester that was built for this project.

In the bottom left corner of figure 2, a small box containing a pump and an electric water heater can be found. In order to maximize gas production, it is important to keep the conditions within the digester suitable for the anaerobic microbes which are actually producing gas. This means keeping the digester warm (no hotter that -40T). For the purpose of this project, 1 have used a small electric heating element and a small pump which will circulate warm water through a coil of 13mm poly pipe inside the digester. Ultimately, on a large scale digester, it would be best to use the gas produced from the digester to provide heating energy for the operation. At the small scale, this is not practical.

Above the water heater and pump in figure 2, a compressor icon can be found. The compressor is used to re-circulate gas through the digester for the purpose of agitation. The effluent being put through the digester will be made up of a mixture of solids, suspended solids and liquids. If this mixture is not agitated periodically, the solids will settle out and cause a scum build-up on the bottom of the digester. In time this scum build-up will cause reduced performance in the digester and it will have to be overhauled and cleaned out. Mechanical agitation can also be used however, problems can occur with mechanical failure and keeping the digester water tight.

The yellow shaded area around the digester in figure 2 represents insulation. Insulation is used mainly to reduce heating costs and to help maintain a homogeneous temperature within the digester. 1 used a sheet metal layer around the insulation as weather proofing. It is important to keep the insulation weft sealed in as birds particularly like the insulation for nesting material.

On the right side of the digester, the effluent inlet pipe can be found. In the diagram you can notice that the inlet pipe is not cut off squarely where it ends inside the digester (see inside the red circle in Fig.2). The microbes within the effluent solution are producing gases which bubble up through the liquid to the gas cavity above. If the inlet pipe was to be cut off squarely, gas may accumulate in the pipe and escape to the outside environment. You will also notice that the inlet pipe extends upwards beyond the level of the effluent in the digester. When the digester is operating, the production of gas will mean that the system will be under a small amount of pressure. This gas pressure may push the effluent level down, forcing the effluent back up the pipe (see fig. 3 below - pressure). Therefore, outside the digester, the inlet pipe must extend above the effluent line to contain the liquid under operating conditions. Inside the digester, the inlet pipe must also extend a sufficient distance below the effluent line to allow for the situation where the gas pressure increases, forcing the effluent level down (see fig. 3 below - pressure).

On the other side of the digester, the outlet pipe can be found. You will notice that this pipe enters the digester and extends up toward the top where there is a tee piece. The stem of the tee goes back down below the effluent level to avoid collecting surface scum from the effluent and also to prevent gas escaping if pressure increases in the system. The point where the outlet pipe meets this pipe will determine the level of the effluent in thedigester with no pressure in the system (this point is labeled point A in Fig.2). The other side of the tee piece which is left open above the effluent level serves two purposes. It allows any gas which accumulates in the pipe to escape to the gas cavity and it also prevents a siphoning effect from occurring when the outlet is being used.

The outlet pipe feeds into the effluent retention sump (figure 2). This device basically acts as a large 'S' bend. It provides a reserve of liquid so that in the case of a vacuum occurring inside the digester, liquid will be sucked into the digester rather than air (refer fig. 3 below - vacuum). Such a situation may arise when the solids valve is opened. It is of paramount importance that outside air (containing oxygen) is not allowed to get inside the digester. This is logical when you consider that "anaerobic digestion" means digestion in an environment absent of oxygen.

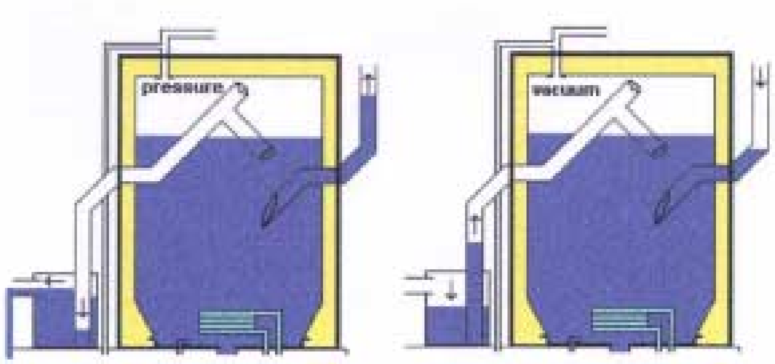

Figure 3 The first digester is showing the effects of pressure on the system. This situation can occur when gas pressure builds up in the system. The second digester is showing the effects of vacuum on the system. This occurs when the solids valve is opened.

The gas outlet on top of the digester in figure 2 goes to the gas inlet on the collector below (Fig. 4).

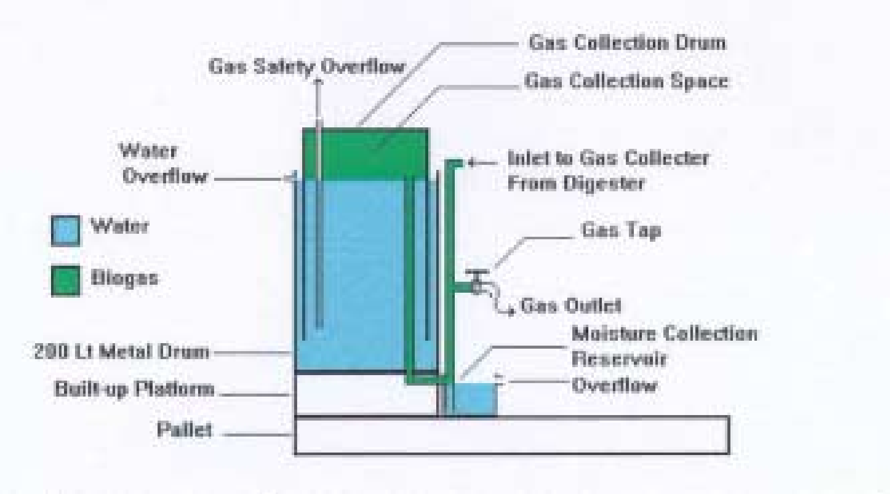

Figure 4 A plan diagram of the gas collector used in this project.

The gas collector shown above is basically a drum that is inverted and inside another drum filled with water. The water acts as a barrier, preventing the gas from escaping from the drum. This device provides a simple gas storage area with a variable volume. The real beauty of this design is that no gas pump is required to shift the gas from the digester to the collector. It simply fills from gas pressure built up in the digester. This part of the design offers significant savings in initial capital costs, running costs, and monitoring costs.

When the gas flows out of the digester and into the collector inlet pipe, it is moving from a warm environment to the cooler outside temperature. The warm environment allows the air to be highly humidified. As the temperature falls, the moisture is no longer able to be suspended in the air and it condenses on the sides of the pipe. If this moisture is allowed to accumulate in any part of the system, it can cause blockages which may lead to increased pressure and possibly even ruptured pipes or vessels. For this reason there is a moisture collection reservoir at the bottom of the inlet pipe in figure 4. This device serves two purposes; to capture and prevent any build up of water in the tube; and also to prevent the gas collection vessel from sucking air in the case that a vacuum is created in the pipe. The moisture collection vessel has an overflow to prevent too much water from collecting.

The gas collection tube has an overflow tube which allow excess gas to be vented off well above ground level. This is simply a tube which extends from about 5Omm above the bottom rim of the gas collection drum and travels up through the top of the drum. When the collection drum is full, the bottom of the overflow tube is exposed from the water and the gas is able to escape.

The tap shown in figure 4 is the main gas outlet where the gas can be tapped off and utilized.

Summary

From the above description of the design features of this project, 1 believe that I have succeeded in meeting the requirements of the brief. 1 am hopeful that the explanations above have given some incite to the design, theory and operation of an anaerobic digester of this type. As mentioned in the introduction, this design is not meant to be revolutionary or radical, it is only aiming to present this concept in a simple, easy to understand format.

With farmers continually facing rising production costs and environmental issues such as the green house effect and waste disposal methods, 1 believe that controlled anaerobic digestion certainly has the potential to provide some solutions to these issues.