A REVOLUTION IN ANAEROBIC DIGESTION

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ABSTRACT:

Man's attempts at reproducing the natural process of anaerobic digestion to clean wastes and produce biogas have, historically, taken place in single cylindrical tanks. Tanks are made in this shape to give simplicity of construction and the minimum use of materials to produce the maximum volume of tank. However they are unsuitable for use in any continuous process which requires a specific retention time and entails thorough mixing. Mixing the contents in a tank of this shape is inefficient when comparing the result with the energy required. Also, partially treated material is present in the final product because full retention time is not achieved due to short circuiting.

If the ends of a sheet of material are rotated towards each other and then joined together, the material takes up a shape where it is in a state of minimum energy forming a tank without any corners. Bubbling biogas along the central cusp of this low energy tank shape creates two opposing circulation patterns within the tank resulting in very efficient mixing of the contents. Adding liquid organic material at the centre of one circulation pattern and removing it from the opposite end of the other circulation pattern gives a continuous plug flow through the tank. Using a series of such tanks for anaerobic digestion results in the complete treatment of organic materials with maximum yield of biogas. These low energy tanks are economical to construct and produce results which far exceed anything previously achieved using cylindrical tanks.

INTRODUCTION:

The process of anaerobic digestion is based on the oldest technology in the world, but it is only relatively recent research which has allowed us to perfect this process for dealing with organic waste which nature has been using for over three thousand five hundred million years. Carried out properly and thoroughly the digestion process (which also includes elements of aerobic digestion) will transform toxic organic materials into clean fertilisers and methane and carbon dioxide gases. The fertilisers will be free of pathogens and weed seeds, the methane gas can be used as energy in the form of heat, fuel for vehicle transport, or for generating electricity and the carbon dioxide can be used in the food and drinks industry, or as an environmentally friendly industrial solvent in the electronics industry.

As humanity becomes more 'civilised', we create more waste, require more food and use more energy, so it should be possible to redress the balance between the increased waste produced and the increased requirement for fertilisers (to grow food) and energy. Unfortunately previous attempts to harness nature's oldest technology have not been entirely successful.

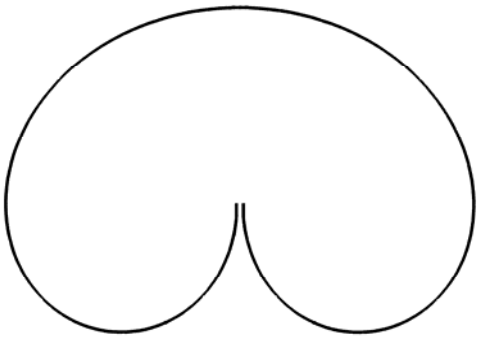
ACADEMIC PAPER:

In order for anaerobic digestion to take place, organic material needs to be contained in a sealed tank for the full process time during which oxygen is excluded, it is exposed to the various families of bacteria, it is kept warm and any addition of feedstock and removal of digestate is carried out gradually to prevent shock loading.

The main problem has been the shape of the sealed tank. Everyone thinks of a tank as a cylindrical object like a baked bean tin, which is made in this shape so as to give the maximum volume of beans for the minimum area of tin. Unfortunately, a liquid contained within this tank shape is extremely difficult to mix properly. There are dead spots around the edges of the base where solids tend to collect and build up over time. It is also quite unsuitable for a process which requires the liquid to remain in the tank for a specific duration before it is fully treated. For example, if this duration is supposed to be 20 days, then untreated material equal to one twentieth of the volume of the tank is added each day, and one twentieth is removed. The problem is that one twentieth of the one twentieth being removed was put in only yesterday, the next twentieth removed went in the day before, and so on. Clearly, material resulting from an anaerobic digestion process in a single mixed tank will be contaminated with untreated material and this is why it smells and continues to give off methane gas.

In order to allow this timeless technology to work properly, we have designed a completely novel shape tank in which the process of anaerobic digestion can take place fully.

A fundamental part of the system is a patented low energy tank based on the natural shape taken up by a strip of relatively stiff material when its ends are rotated in opposite directions and then held together. The material takes up this specific curve in order to form a shape where it is in a state of minimum energy:



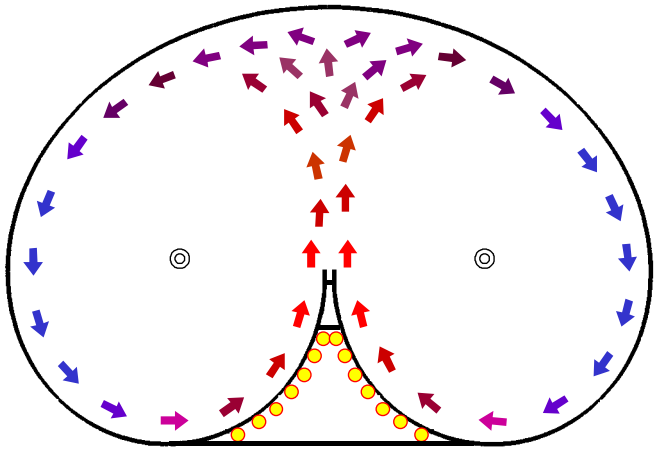
Although a natural shape, the curve is actually very complex and is described by the formula:

$$\tfrac{1}{24} Q a^3 \int_{-L/2+\varepsilon}^{+L/2-\varepsilon} \left(\frac{\partial \phi}{\partial l} \right)^2 dl$$

Where Q is the appropriate modulus and ϕ is the tangent angle made by the cross section at a length l around the tank measured from the apex.

Fitting two flat ends on to this minimum energy shape creates the form of the tanks used in the Maltin® System which are the basis for the process which has now been licensed to Organic Power Limited:

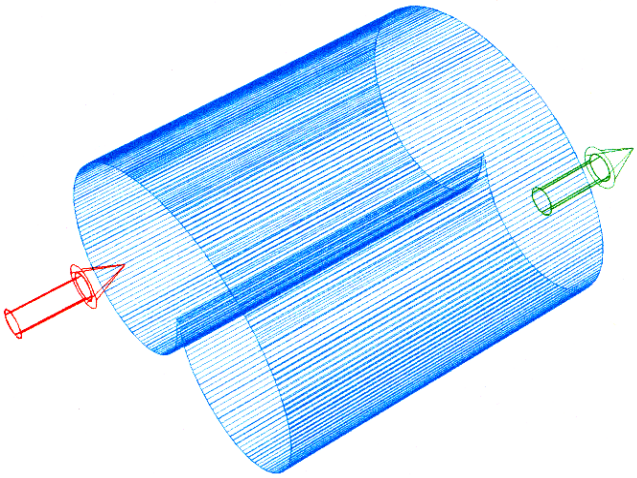
Heating the lower part of the tank and bubbling gas from along the central cusp inside the tank causes the liquid contents to rise vertically from the centreline of the tank and then to form two opposing circulation patterns, being constrained by the minimum energy curve of the tank walls. This results in very efficient and thorough mixing of the contents which ensures complete degradation of the organic matter and the maximum production of methane:



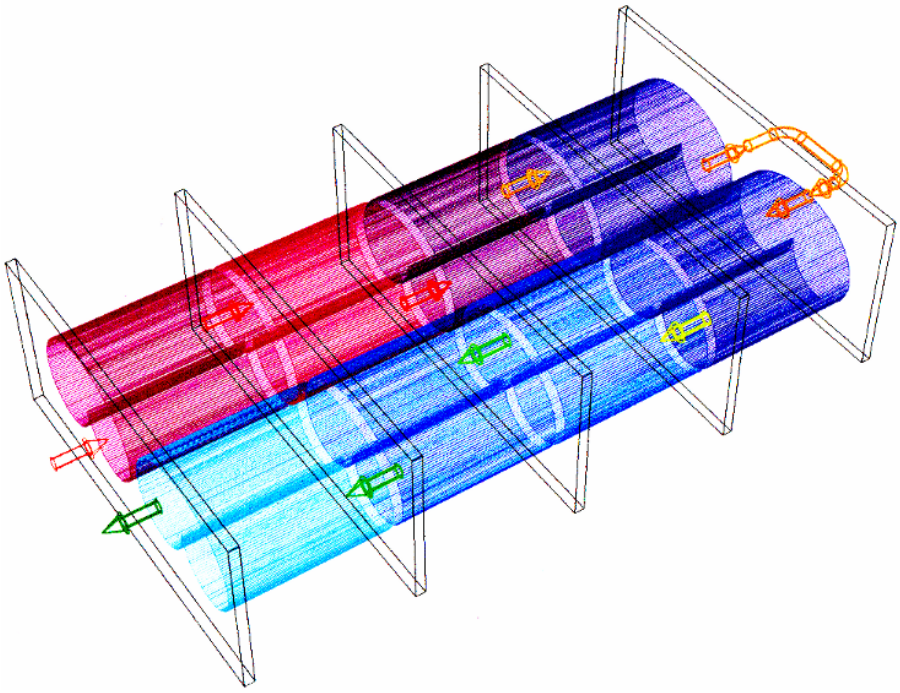
At the centre of each flow pattern is an "eye" in the circulation path as marked with double circles in the diagram above.

Filling the tanks with liquidised organic waste such as vegetable and meat scraps and excluding air will cause anaerobic bacteria to multiply and generate methane gas, provided the contents are warmed and stirred continuously.

By adding liquid organic material at this eye point the circulation patterns are hardly affected. Similarly the treated organic material can be removed from the corresponding eye at the other end and in the other half of the tank. This addition and removal of material has minimal effect on either of the two main circulation patterns and so a continuous process can be maintained with material passing slowly through the tank.



The path taken by the organic material also ensures it is completely treated, particularly if a number of such tanks are grouped together:



RESULTS AND DISCUSSION:

The complete treatment of organic materials as they pass through this series of tanks brings about their transformation from wastes into valuable resources. The carbon dioxide gas produced is valuable to the food and drinks industry and, as supercritical CO_2, is being increasingly used in the electronics industry to replace solvents for cleaning. The methane is a valuable renewable energy source which is carbon neutral and one of the cleanest fuels known. The clean fertilisers produced give superior crops and require less water than artificial fertilisers.

Dwindling natural resources, a shortage of food, water and energy, and environmental pollution are some of today's global problems which need to be solved.

We believe that this demand for energy and food can be satisfied, and water requirements and pollution can be reduced, by using this system to process unwanted organic material. The design of the low energy tanks described is such that they can be mixed and heated using solar energy. As no external power is required for the actual process, all the methane gas is available as a renewable and clean energy source.

CONCLUSIONS:

There are three basic methods of dealing with the organic wastes produced by society. Basically the wastes can be buried, burnt or biodigested.

In practice the principle technologies are landfilling (including 'seafilling'), incineration, gasification, pyrolysis, vitrification, composting and anaerobic digestion.

Anaerobic digestion is the only environmentally friendly way of treating organic wastes sustainably.

There are European Directives which give all the reasons why landfilling is not an option for organic wastes and disposal at sea has been banned since January 2000.

Any forms of incineration, whether mass burn, gasification, pyrolysis or vitrification are not sustainable. Although energy is produced during these processes, the additional energy required to produce the mineral fertilisers to replace the fertiliser value which has been destroyed by the burning process, results in nett reduction in the energy produced.

Composting requires an energy input and the process gives rise to harmful gaseous emissions.

Anaerobic digestion is sustainable, environmentally friendly and has no emissions to atmosphere. The process is a nett producer of carbon neutral renewable energy and clean fertilisers.

SUMMARY:

Organic waste is a renewable resource that is produced worldwide wherever there is life. Harnessing this time honoured natural process of anaerobic digestion is a means of contributing towards the fertiliser and energy required to support this life in a sustainable and environmentally friendly manner.

