MAF

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Energy Biogas Production

By the UASB Process

The decomposition of organic matter and its conversion to useful biogas fuel is a well established process. In the conventional process agricultural solid wastes or slurries such as poultry, pig and cattle manures, weeds, or crop residues, are loaded into a large closed tank called the digester. In the digester the organic matter is warmed to 30-37°C and mixed together with bacteria which act in the absence of air to convert the organic matter to biogas (anaerobic digestion).

However, conventional biogas plants can only be used successfully with wastes that contain at least 3-5% solids. When the waste is too watery it requires too much heating to raise its temperature to 30°C, and contains too little organic matter that can be converted to biogas to fuel the heating. In addition, a large volume of waste must be loaded into the digester in order to produce a useful output of biogas, and this high flow of liquid tends to wash the bacteria out of the digester, causing the process to fail.

The UASB process

The UASB (Upward-flow Anaerobic Sludge Blanket) process is especially designed to enable treatment and/or utilisation of watery wastes. A special design of digester (Fig.1b) prevents bacteria being washed out and encourages the development of a bed of sludge containing high numbers of bacteria. The wastewater is pumped in at the bottom of a UASB digester and flows upwards through the sludge bed. The bacteria in the sludge convert the organic matter in the wastewater to biogas as it passes through.

The bacteria

The success of the UASB system depends partly on the design of the digester and partly on the development of the bed of bacteria. The bacteria are not different species to those found in a conventional digester. What is different is that they cling together to form clumps of bacteria, often of a single species. The clumps sometimes become granules as large as 1-3 mm in diameter, especially when the waste water contains sugars. The granules are heavy and settle quickly, even against the upward flow of the waste water, so that they do not get washed out of the digester. However, although the granular bacteria are

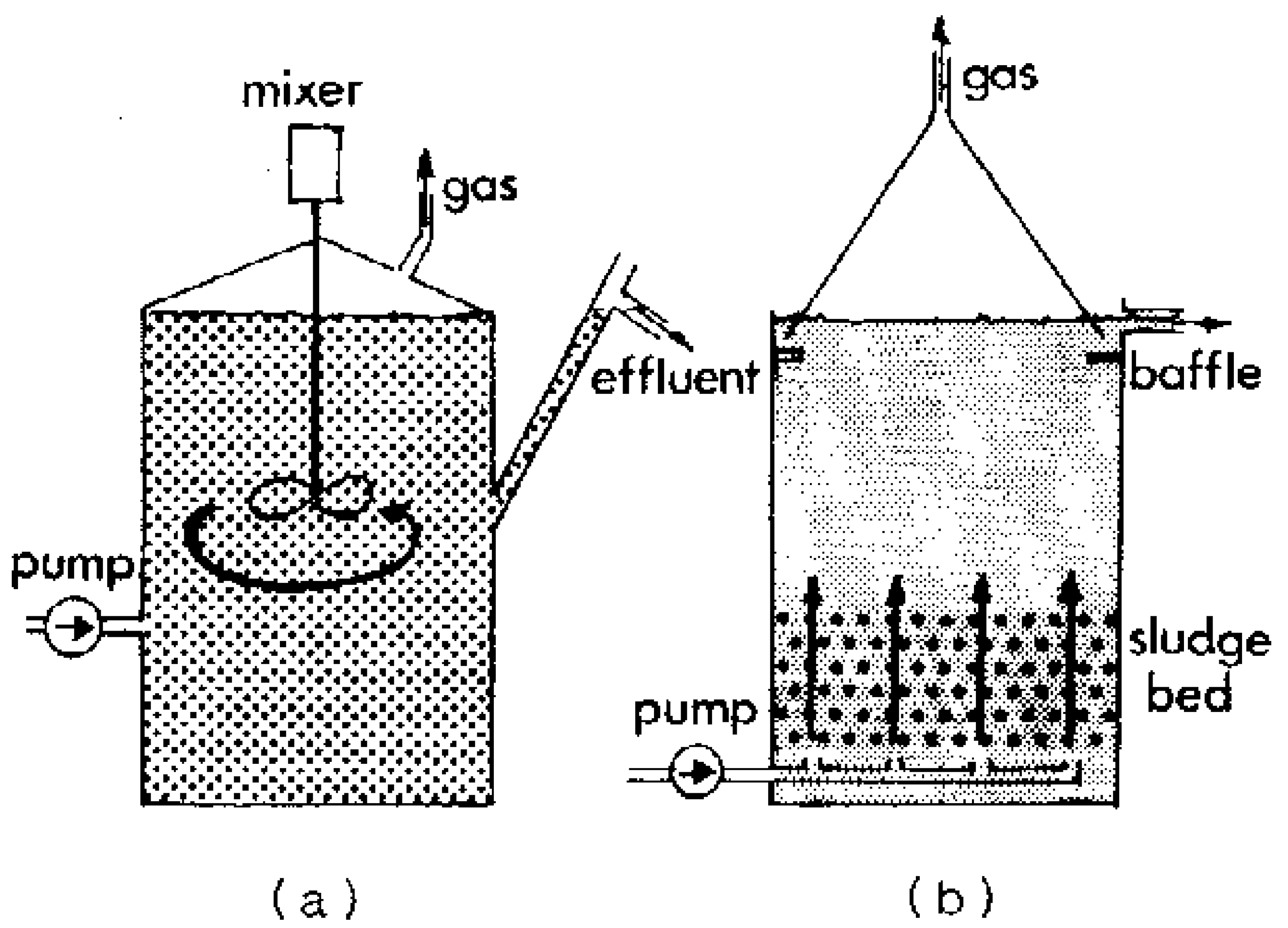

Fig.1: Conventional mixed and heated digester (a) and UASB type digester (b).

usually best, a sludge that does not contain distinct granules but does contain a large number of bacteria and settles well can also be satisfactory.

The discovery that bacteria can form granules is quite recent, and so far little is known about how they do so and why. There are only 'recipes' for how to encourage the development of a suitable bacterial sludge or granules, which can take 6-12 months in practice. A UASB digester can be started much more quickly when sludge from an operating UASB digester is available. Fortunately, the sludge can be stored for up to a year and still remain active, so that it is possible to transport it over long distances. It is also possible to 'seed' a digester with granular sludge which encourages the development of more granules.

UASB digester design

A UASB digester is made from a tank that is open at the top. A cone or tent is then installed over the top to collect the biogas produced and to return solids that float to the surface with the gas bubbles. To prevent the escape of gas around the sides of the cone, baffles are fixed to the tank walls. A simple design is shown in Fig.2.

A system of distribution pipes must be provided at the bottom of the digester to make sure the wastewater flows evenly upwards through the sludge bed, and not through holes or channels. The evenly distributed upward flow of the wastewater also helps suspend the sludge in the digester.

More complex designs of gas collector/solids separator have been developed and patented. They allow higher rates of wastewater flow through the digester and better retention of bacteria against washout.

The UASB loading pump should be of such a capacity that it can pump the daily quantity of wastewater through the digester over a 24 hour period. A variable speed pump is useful for adjusting flow rates.

A sludge drain should be provided to enable removal of grit and surplus sludge.

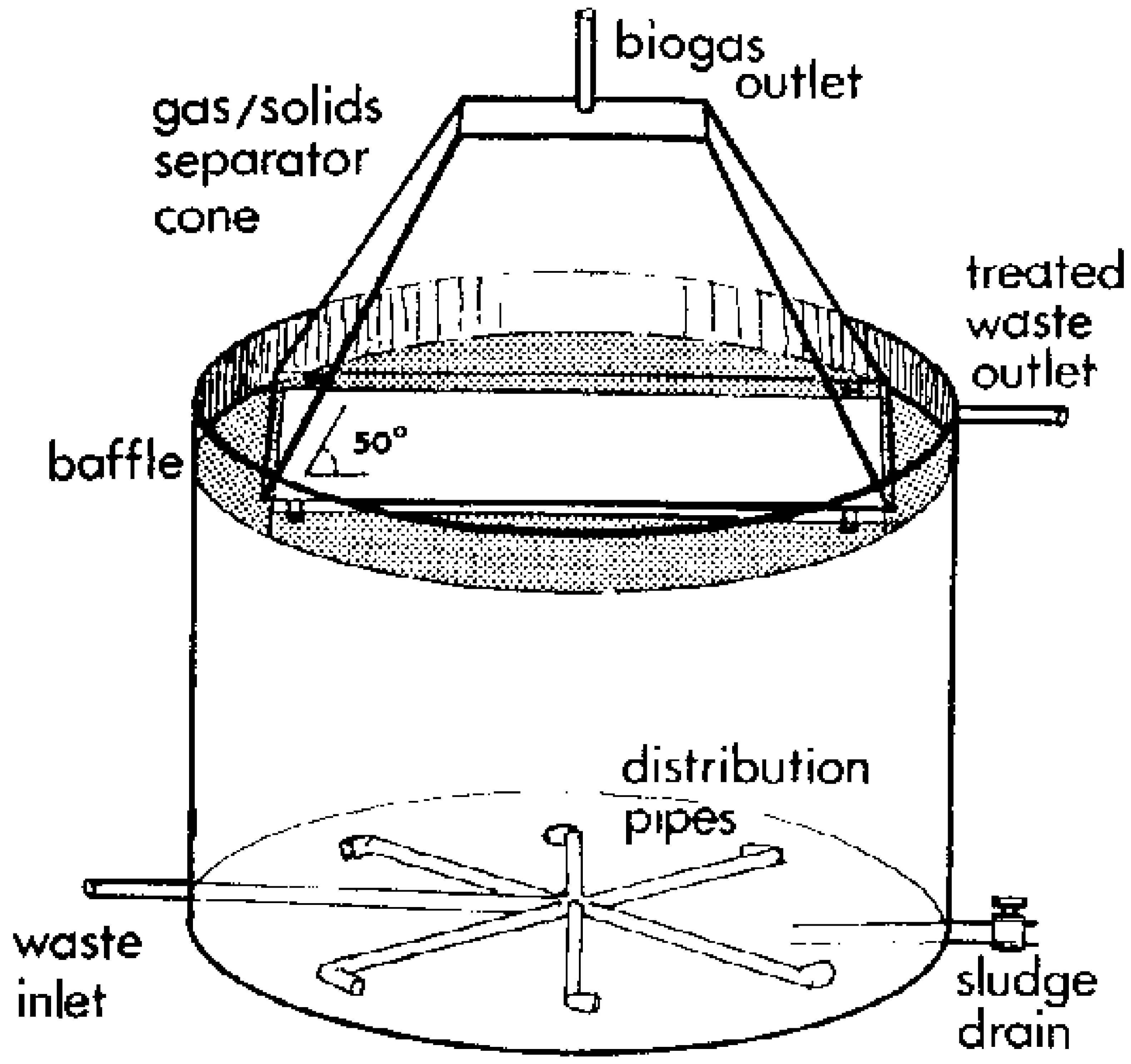

Fig.2 Design of simple UASB type digester showing gas collection/solids separation cone and influent distribution system.

Temperature of operation

The bacteria in the sludge bed work faster at 30-37°C as in a conventional digester, and best results are obtained if the wastewater is heated to this temperature range. At 30-37°C organic matter can be converted to biogas in as little as 4 hours, compared to 2-3 weeks in a conventional digester. This fast conversion results from the high numbers of bacteria in the sludge bed, as well as the soluble nature of the wastewaters that can be digested by the UASB process.

The high numbers of bacteria also allow wastewaters to be digested at temperatures as low as 10°C, at a rate and efficiency similar to that of conventional digestion at 30-37°C. This enables a wide range of high volume, low temperature wastewaters to be treated/utilised by the UASB process, without any heating being necessary.

Suitability of wastes for treatment

The UASB system is designed to handle watery wastes containing dissolved organic matter and/or up to 1% solids. Greater amounts of solids are likely to clog the bed of bacteria, impairing its ability, or even push the bed out of the digester, especially if the solids tend to float. Wastewaters containing more than 1% solids have to be screened or held in settling tanks to separate the solids. The separated solids could then be digested in a conventional digester, if desired.

Readily digestible organic matter is most suitable for digestion in a UASB system, such as wastewaters from sugar factories, fruit and vegetable processing, starch manufacture, distilleries, and whey from dairy factories. Other wastewaters such as those from meat works, wood processing, tanneries, woolscours, dairy sheds and piggeries can also be handled satisfactorily.

With watery wastes the concentration of organic matter cannot be judged from the solids content because much of it may be dissolved. A laboratory test must therefore be made of its strength, referred to as Chemical Oxygen Demand (COD). Table 1 lists some typical strengths of various wastes that can be treated by the UASB process.

If a waste contains a very high concentration of organic matter (COD greater than 10 g/L), it has to be diluted before pumping to the UASB digester. This is usually done by recycling treated wastewater at an appropriate rate.

Table 1: Typical strengths of various wastes that can be digested by UASB

Waste	Strength TS(%)*	Strength COD(g/L)
Piggery washings (screened)	1	8
Dairy shed washings	1-2	3-8
Dairy factory whey	0-1	80-100
Meatworks wastewater	1	1.5-2.5
Distillery wastewater	-	50-100
Raw sewage	0-1	0.2-0.9
Paper mill wastewater	1	6-10
Potato processing wastewater	0-1	3-7

TS = total solids
COD = chemical oxygen demand

UASB digester volume

It is not as easy to calculate a suitable volume for a UASB digester to treat a particular waste as it is for a conventional digester. The size will depend on the composition of the waste, its strength, volume, and temperature. Laboratory analyses and testing of individual wastes are essential.

However, as a rule of thumb, 0.1 m^3 of UASB digester volume should be allowed for each kg of COD to be treated per day at 30-37°C, or 0.5 m^3 at 10-15°C. In addition, for every m^3 of waste volume a minimum of 0.2 m^3 of UASB digester volume should be provided at 30-37°C, or 0.5 m^3 at 10-15°C.

Biogas production

The volume of biogas that will be produced depends on the composition of the waste being treated, how much can be loaded into the UASB digester per day, and the temperature. Typically, about 375 L of biogas containing 75% methane will be produced from each kg of COD loaded at 30-37°C, or about 300 L/kg COD at 10-15°C.

The concentration of methane in the biogas from a UASB digester is usually high because of the watery wastes treated. Much of the carbon dioxide produced dissolves in the wastewater, and biogas with as much as 95% methane can be produced in some cases.

Applications of the UASB process

Full scale UASB digesters are now in commercial operation in many countries treating a wide variety of processing wastewaters. Some have been in operation since 1976. In NZ one large meatworks has had a 4200 m^3 UASB digester in operation since 1982 treating the works wastewater. The digester operates at temperatures as low as 8°C, and produces about 3000 m^3 of biogas each day containing more than 90% methane, equivalent to about 2500 L of diesel oil in fuel value. The biogas is currently used to fuel wool driers at the works.

A small UASB digester for dairy or piggery wastes

A small UASB digester can be built from a 22.7 m^3 (5000 gal.) precast concrete water tank, made with an open top and fitted with a gas/solids separator 'cone' and gas baffles as shown in Fig.2.

This size of digester could treat the dairy shed wastes from about 125 cows (assuming they spend 2 hours/day in the shed) or 50 housed pigs. About 10 m^3 of biogas could be produced from the dairy wastes and 15 m^3 from the piggery waste each day, with an energy equivalent of 8 and 12 L diesel respectively. Larger numbers of animals would require a proportionately larger volume of digester.

The gas/solids separator 'cone' should preferably be made from PVC sheet or fibreglass to resist corrosion, and must be gas tight. The baffles can be made from PVC or light steel, and must be securely fixed to

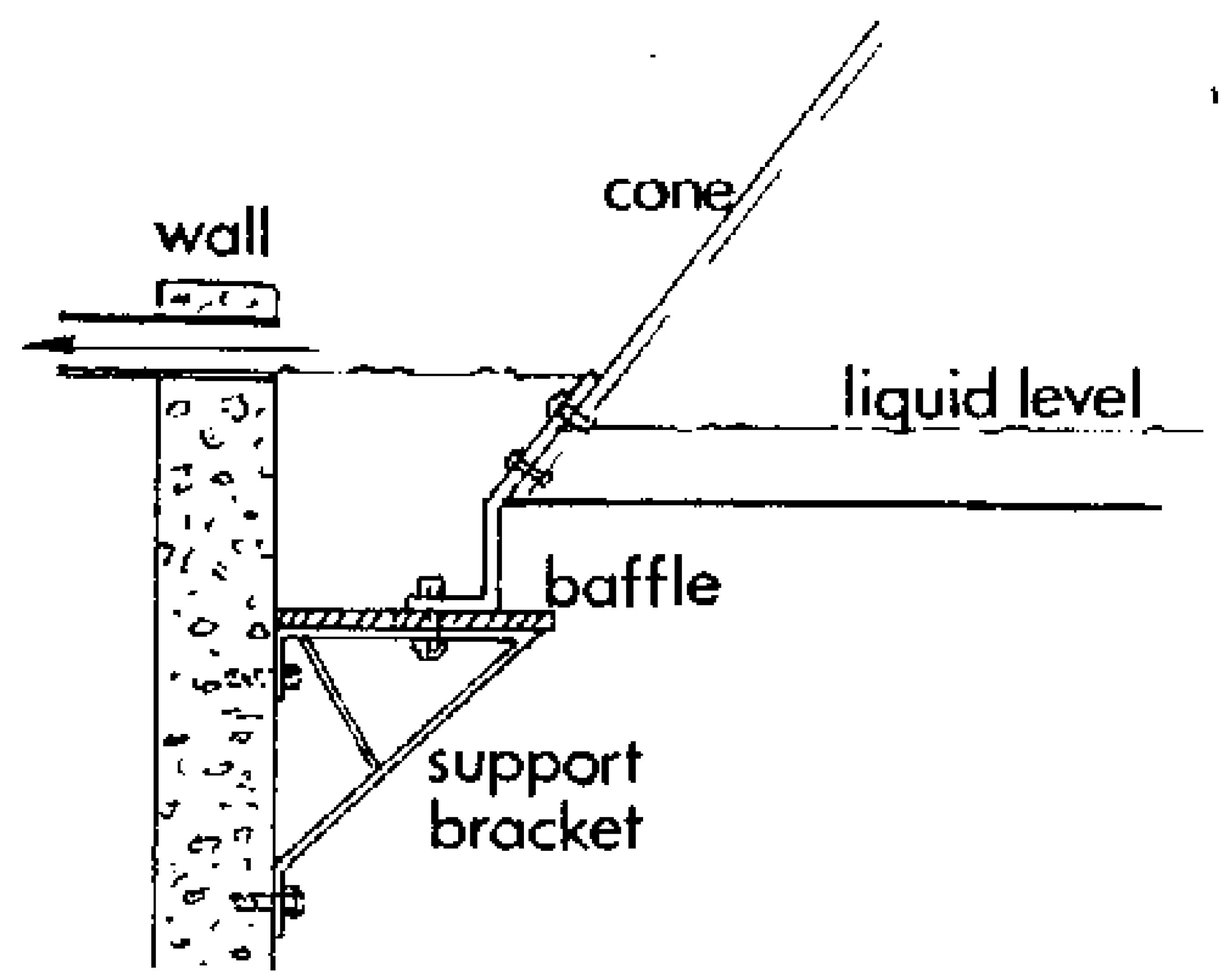

Fig.3: Details of construction of UASB digester - baffle and cone assembly.

the digester wall to support the weight of the cone until the digester is in operation (see Fig.3). In operation the gas filled cone will have little weight, and the bracket connecting it to the baffle will serve to anchor it.

The other components required are a sump to hold the day's production of waste and a pump of suitable capacity to load the waste over a period of about 20 hours (i.e 40L/min.). Float switches will need to be fitted in the sump to switch the

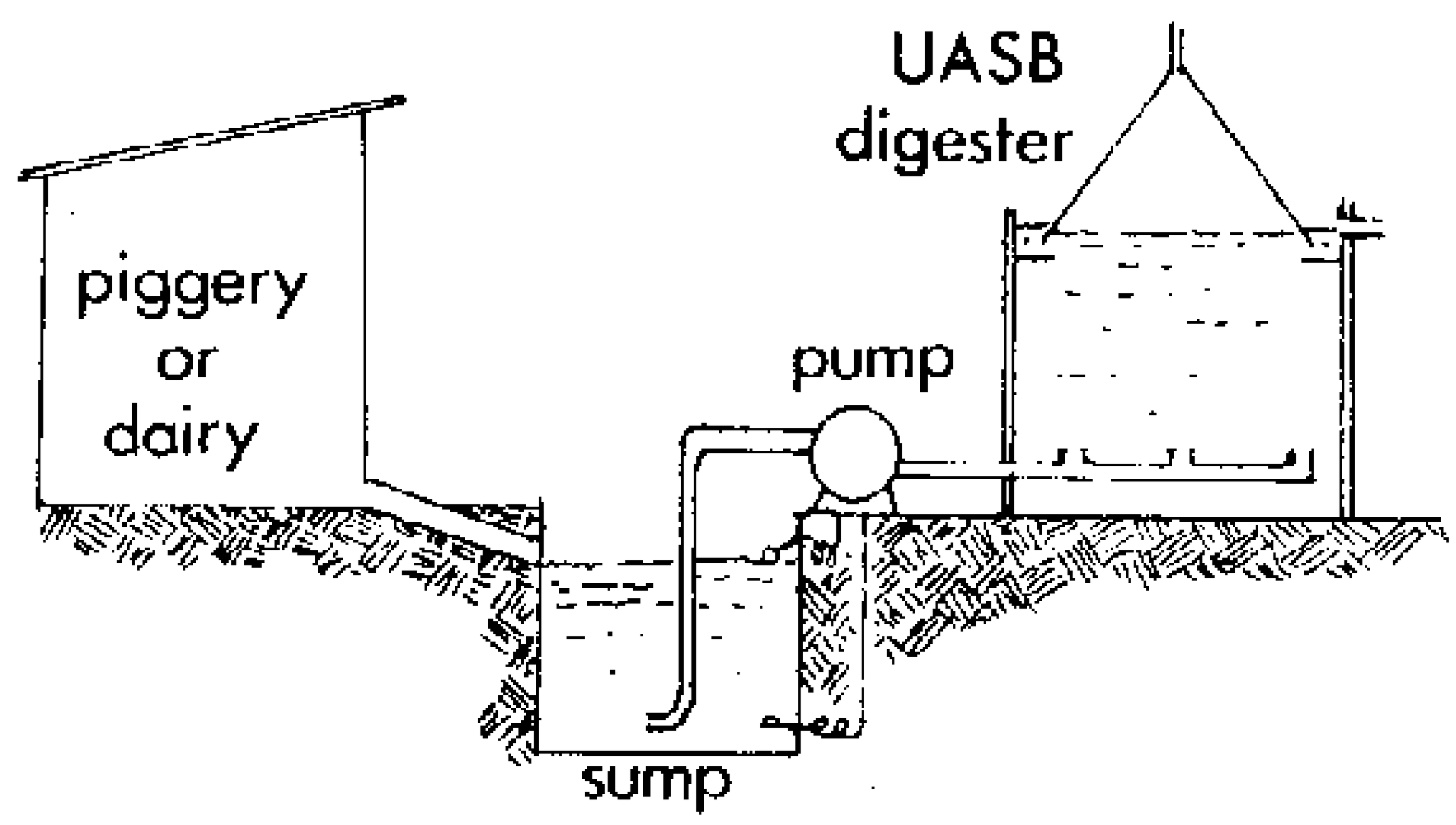

Fig.4: Layout and components of a small UASB system for dairy or piggery wastes.

pump on when it is full and off when empty.

Treated wastewater from the UASB can flow to a storage tank or lagoon before being sprayed onto pasture or discharged to a stream, if allowed.

If the biogas produced is to be used for heating etc, the outlet from the UASB digester will need to be connected to a butynol gas storage bag or steel gasometer. The gas can be burned in standard appliances designed for use with natural gas, but better results are obtained by enlarging the gas jets slightly.