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GAS MEASUREMENT METHODS FOR LABORATORY-SCALE ANAEROBIC REACTORS

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Abstract

Various methods exist to measure gas production from anaerobic reactors but not all can easily be used to obtain the rate directly, and some are limited by small flow rates. A review of gas measurement methods is given. Two simple online gas monitoring systems, are described. The reactor design with respect to liquid overflow and gas take-off is shown to be important.

Introduction

One of the disadvantages of the anaerobic digestion processes is that they are prone to instability because of the coexistence of two main groups of bacteria (acido- and methanogenic), whose conversion rates must be balanced to prevent inhibition due to acid accumulation and a consequent halt in methane production.

The rate of gas production, mainly methane, is the most important indicator of operational performance . As a direct measure of the activity of the methanogenic bacteria, it is an important diagnostic tool for digester performance. Any change in gas production rate can be used to analyze the reactor performance. Instantaneous gas flow rates are more useful than gas volume accumulation over long time periods. This is because the total biogas volume over a long time reflects events which have already taken place. In contrast online measurement of gas flow rates can provide information about the reactor that reflect the momentary situation, making them useful as a controlling and diagnostic parameter. Additional methane content information can be used as a direct measurement of COD degradation rates, since 1kg COD degraded produces 350 L CH_4 (STP).

This contribution gives recommendations for equipment design with respect to liquid effluent overflow to obtain the most accurate gas flow measurements. Gas flow measurement devices are described and recommendations for laboratory-scale application are given.

Review of the Existing Methods for Measuring Gas Production

Instantaneous gas flow rates would be useful for kinetic experiments. However, with the available methods, rates must be obtained from volumetric measurements over a suitable short time period. The basic instrument is perhaps the wet gas meter, which is often too large for small reactors. The inverted submerged gas bottle method, or the equivalent Mariotte

bottle method (Gorris et al., 1988) is simple and accurate. A U-tube filled with liquid can also be used to measure the gas volume, with the disadvantage that the pressure varies but having the advantage that it is easy to set up and automate. The literature reports on an automated, offline, batch measurement cell method involving liquid level in a straight tube manometer, measured by a light beam (Van den Berg et al., 1974). A continuously operated minireactor was monitored with an automated U-tube device to measure both gas rate and total gas production (Dissing et al. 1984). This is similar to the device used in the present work. Pressure transducers are mainly for closed reactors with very small gas rates (Battersby and Wilson , 1988; Shelton and Tiedje, 1984) but could also be used on tank reactors if the system were intermittently closed.

Materials and methods

Biofilm Fluidized Reactor

The gas measurement techniques were tested on laboratory-scale anaerobic biofilm fluidized beds., built of standard glass parts fitted together with tapered joints as shown in Fig. 1. The reactor column was approximately 0.8 L total volume, with a height of 70 cm and an internal diameter of 3 cm. The conical upper settling zone was specially built and had a diameter of 10 cm. The reactor contained initially 70 mL settled volume of the support material (0.2-0.3 mm quartz sand). The upflow velocity rate through the column was adjusted to achieve an expansion between 50 and 200% of the static height. Circulation and fluidization flow rates were maintained with a peristaltic pump using Marprene tubing. The feed was introduced into the system on the suction side of the recycle pump using a multi-channel peristaltic pump. The reactor was fed continuously and the liquid and gas effluents flowed at the top of the column through a level-controlling overflow into a gas-liquid separator. The reactor temperature was maintained at 37^{0} C by a heat exchanger in the recycle line.

Design of the Liquid Overflow

Critical to successful gas flow measurement is the design of the liquid overflow and gas collection from the reactor to prevent a change in the liquid level, due to the pressure drop caused by gas measurement. Often, the gas is taken off the top of the column and the liquid effluent leaves through a side tube, which is located below the liquid surface and connected to an overflow chamber. This design will cause problems because gas over-pressure, due for example to the flow measurement method, will push down the liquid level and force the liquid out of the reactor into the overflow chamber. Due to the large surface area, a small change in level represents a large change in gas head space volume.

To prevent this, the effluent gas and liquid should overflow at the top of the column, either over the rim or through a large tube, to a second overflow-separator, as shown in Fig. 1 (Toldra' et al., 1986). In this way the pressure drop of the gas flow device will not alter the position of the liquid surface, and hence the volume of the gas head space, which would falsify the volumetric measurement. A small, but controllable, volumetric change still occurs since the liquid in the overflow tube of the separator is pushed down, corresponding to the final outlet gas pressure. Gas could also be taken off the top of the column but this design permits visual observation of the bubbling gas flow. This overflow design applies, of course, also to tank systems.

Experimental Results

Fig. 2 gives data of gas flow rate results from three methods of measurement obtained using the new overflow reactor design. Here the gas meter, known to be correct by calibration, is compared with the inverted gas bottle and the U-tube methods. The measured flow volumes were divided by the time to obtain the rates. Because of the equipment size, each device required a minimum time at these low flow rates to obtain the necessary accuracy: wet gas meter (3h), inverted gas bottle (3 min), U-tube (1 min). It is seen that all methods gave essentially the same results, within 5%.

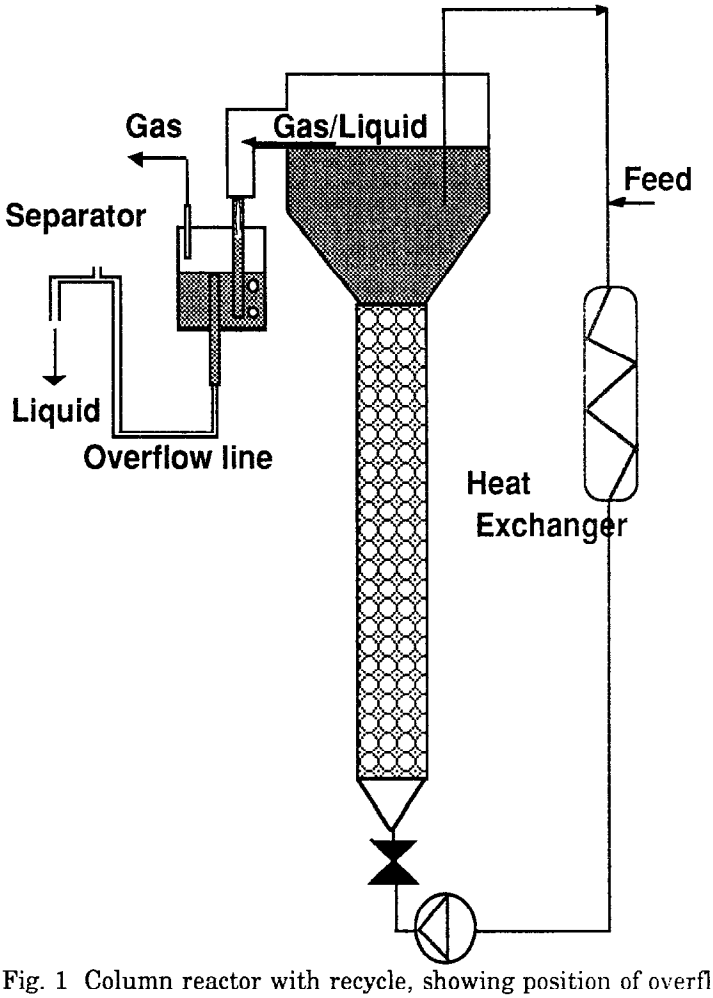

Fig. 1 Column reactor with recycle, showing position of overflow and design of gas separator.

Discussion

It is interesting to consider automation of either the U-tube or to the inverted gas bottle (graduated cylinder), as shown in Fig. 3. For automation, it would necessary to measure the liquid levels, here with a light beam device (Van den Berg et al., 1974; Dissing et al.,1984) but an inductive device could be used. The liquid must be releveled in the U-tube liquid with an exhaust valve or refilled in the case of the inverted graduated cylinder (here with a mechanism for raising and lowering). A Mariotte bottle (not shown) could be placed on a recording balance to determine the displaced liquid and refilling could be done via a standpipe and exhaust valve manipulation.

The convenient peristaltic recycle pumps, often used in laboratory reactors cause pressure oscillations, which can be partially damped by restricting the gas outlet flow. The remaining oscillations proved to be too large for the use of some flow instruments, such as the mass flowmeters and gas bubble devices. These devices would be suitable for stirred tank reactors. Rotameters have not proven to be suitable; they are either too large or too prone to clogging or sticking.

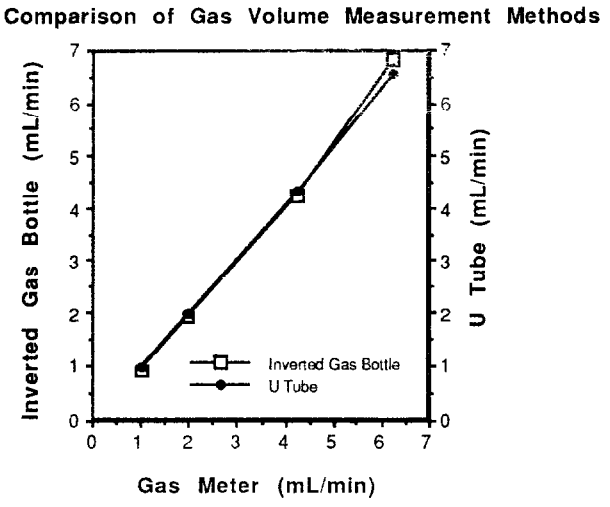

Fig. 2 Comparison of flow rate measurement methods using the improved reactor design.

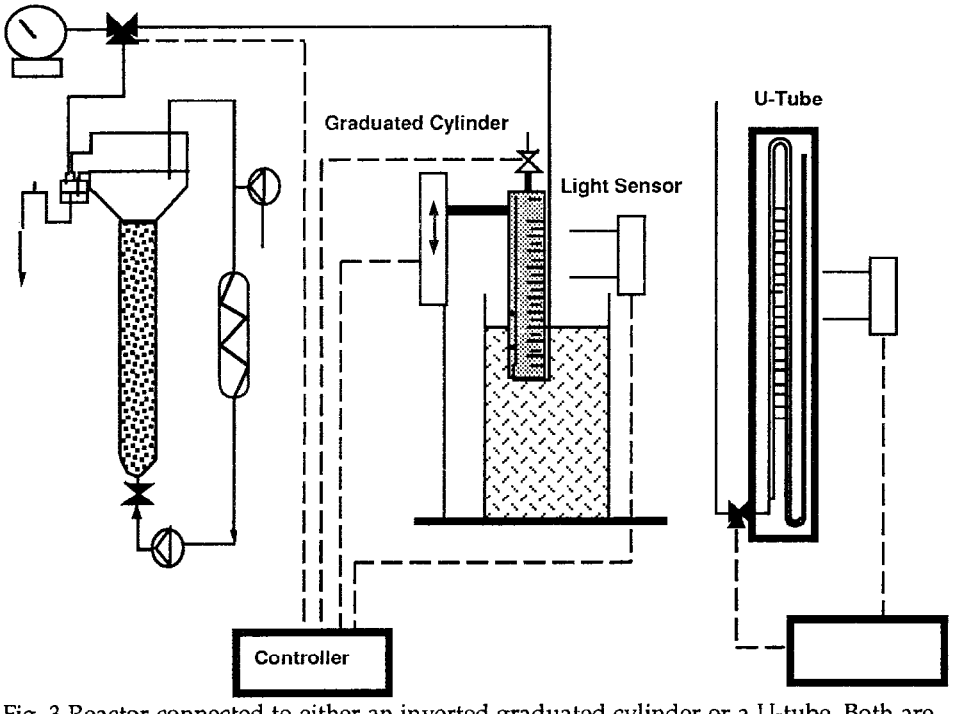

Fig. 3 Reactor connected to either an inverted graduated cylinder or a U-tube. Both are depicted as being automated by suitable sensors, refill arrangements and controllers.

References

Battersby, N.S., and Wilson,V. (1988). *Chemosphere,* 17:12, 2441-2460.
Dissing, U., Ling, T. G., Mattiasson, B., (1984). *Anal. Chim. Acta,* 163, 127-133
Gorris, L. G., van Deursen J. M. A., van der Drift, C., Vogels, G. D., (1988).
Appl. Microbiol. Biotechnol. 29, 95-102.
Shelton, D.R., and Tiedje, J.M. (1984) *Appl. Environ. Microbiol.* 47, 850-857
Toldra',F., Flors, A., Lequerica, J. L., and Valles S. (1986).
Appl. Environ. Microbiol. 23, 336-341.
Van den Berg, L., Lentz, C. P., Athey, R. J. , and Rooke, E. A. , (1974).
Biotechnol. Bioeng. 16 II, 1459-1469.