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ANAEROBIC TREATMENT BY UASB OF AGRO MILL BLACK LIQUOR

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Abstract

Anaerobic wastewater treatment of Agricultural residue based pulp mill Black liquor could become necessary, as it generates surplus energy, instead of consuming energy as in conventional ETPs. High Rate Anaerobic reactors, like UASB, not only save valuable energy by reducing requirement of aeration substantially, but save coal as well, by burning methane produced in the process, in boiler. We have done extensive tests in our laboratory, set up by two students trained at Agricultural University of Wageningen, Holland. We are reproducing some results here, and also offer our pilot plant for trials at Mill sites.

Anaerobic digestion as a waste water treatment method and energy saving and production method has considerable potentials for both developing countries as well as for technologically highly developed countries. Fortunately these potentials are being recognised by an ever growing group of specialists working in the field of environmental protection, particularly since the first full scale plants have demonstrated the feasibility of the process.

At the present state of process technology of anaerobic treatment, little of the drawbacks of the process are left, and all of its benefits are still alid (see Table 1 for the benefits and drawbacks).

Moreover a valuable compound like ammonia is conserved in the process; in cases where the effluent can be employed for irrigation – as presumably is the case for India – the presence of this compound together with PO¾– represents an important additional benefit, because it will lead to a save in hard currency to purchase fertilizers.

TABLE I

BENEFITS AND LIMITATIONS OF ANAEROBIC TREATMENT OF WASTEWAT ERS

Benefits	Limitations
1. Low production of waste biological solids	1. Anaerobic digestion is a rather sensitive process, e.g. the presence of specific compounds, such as CHCL3, CCI4 and CN-
2. Waste biological sludge is a highly stabilized product that as a rule can be easily dewatered	2. Relatively long periods of time are required to start- up the process as a result of the slow growth rate of anaerobic bacteria.
3. Low nutrient requirements	3. Anaerobic digestion is essentially a pretreatment method; an adequate post - treatment is usually required before the effluentcan be discharged into receiving waters.
4. No energy requirement for aeration.	4. Little practival experience has been gained with the application of the process to the direct treatment of wastewater.
5. Production of methane, which is a useful and product.	
6. Very high loading rates can be applied under favourable conditions.	
7. Active anaerobic sludge can be pre-served unfed for manv months.	

Undoubtedly a serious drawback of anaerobic digestion is its high sensitivity for a number of compounds, as the methanogenic organisms are extremely susceptible. Fortunately most of the more harmful compounds commonly do not occur at inhibitory levels in effluents of agricultural industries, and consequently generally little if any problems will be encountered in the application of the process for these types of wastes. Moreover even for those cases where some of the compounds might occur at toxic levels (or might be formed as an intermediate), serious problems frequently can be prevented by allowing the system to acclimatize or by applying a proper pretreatment, e.g. a stripping process. In specific cases an acidigonesis step prior to the methanogenesis might represent an attractive solution.

The anaerobic digestion process is a bacterial fermentation by which organic matter is converted to carbon dioxide and methane. It occurs naturally in river sediments, marshes and in the rumen of cattle and sheep.

As a treatment process for organic wastes its most notable features are that it destroys organic pollutants without requiring any additional oxygen and that it produces a useful by-product, a geseous fuel containing about 60 percent methane.

The anaerobic digestion process is already widely used for the stabilisation of sewage sludges prior to their disposal onto farmland. Here its major advantages are the destruction of odours and of pathogens which permits disposal of the sludge with a minimum of nuisance and of risk to public health. The process is also suitable for the stablisation og animal manures and other strong organic wastes popularised as 'Gobar Gas Plants'.

In recent years, interest has centred on the use of the process for the partial purification of indsutrial waste waters.

Process Kinetics of the Methane Fermentation

The overall reaction rate of the methane fermentation is controlled primrily by the growth rates of the bacteria involved and in particular by the growth rates of the bacteria which actually generate the methane for this is generally taken to be the ratelimiting step.

Gas Yield Coefficients

Some theoreticals gas yield coefficients are listed in Table II. These conversion factors refer only to the proportion of the incoming organic matter that is actually converted to gas, Before using them one must first deduct the fractions that are converted to biomass or discharged in the effluent as unreacted substrates. Also it should be noted that these gas yields are quoted at NTP (*) and include the gas that remains dissolved in the digester effluent. Because carbon dioxide is more soluble that methane, the gas collected from a digeser will be reduced in volume and increased in quality by this solubility effect. For example, the gas produced by the digestion of crbohydrates always contains 50 per cent methane by volume but the gas collected will typically contain 55-60 per cent methane because a proportion of the carbon dioxide remains in solution.

In recent years energy considerations and environmental concerns have increased the interest in direct anaerobic treatment of industrial wastes. The anaerobic method of waste treatment offers, under the present circumstances, a number of significant advantages with little serious or insuperable drawbacks over other treatment methods. Benefits and limitations of the process have been summarized in Table 1.

TABLE I

THEORETICAL GAS YIELD COEFFICIENTS FOR THE ANAEROBIC DIGESTION PROCESS (See Text)

Type of organic digested	waste water matteranalysis	Methane yield coefficient (m^3/kg)	Gas yield coefficient (m^3/kg)	Percent methane in gas
All types	COD (1)	0.35	—	—
All types	TOC (2)	—	1.87	—
Carbohydrates	VS (3)	0.39	0.79	50
Fats	VS	1.03	1.44	72
Proteins ($C_8H_{14}O_3N_2$)	VS	0.51	0.96	53
Acetic acid	direct determination	0.37	0.75	50
prpionic acid	((	0.47	0.81	58
Methanol	((	0.84	1.12	75
Ethanol	XX	0.73	0.97	75

(1) COD = (Chemical Oxygen Demand)
(2) TOC = (Total Organic Carbon)
(3) Vs = (Volatile Solids) = Organic Solids

Anaerobic Waste Treatment Methods

The loading rates permissible in an anaerobic waste treatment process are primarily dictated by the sludge retention in the anaerobic reactor. The maintenance of a high sludge retention time (SRT) has been at least until recently - the major problem in the practical application of the process, especially for wastes with a chemical oxygen demand (COD) below about 3000 mg/ltr.

Obviously a waste treatment process for low-strength wastes is an economical one if large volumes of waste can be forced through the system in a relatively short time period. For this purpose processes are required in which the biomass retention time can be controlled independently of the wasterwater flow rate. Conventional anaerobic treatment processes of the flow-through type are therefore inadequate to treat low-strength wastes. The solution for the biomass retention problem resulted in the development of different anaerobic treatment processes. These systems have been schematically presented in Figure 1.

The essential feature of the "anaerobic contact" process is that the wash out of the active anaerobic bacterial mass from the reactor is controlled by a sludge separation - and - recycle system. The major problem in the practical application of the contract process has always been the separation (and concentration) of the sludge from the effluent solution. For this purpose several methods have been used or were recommended for use. e. g., plain sedimentation, settling combined with chemical flucculation with vacuum degassification, or ever with aeration, flotation, and centrifugation. A basic idea underlying the contact process is that it is considered necessary to thoroughly mix the digester contents, e.g., by gas reciculation, sludge recirculation, or continuous or intermittent mechanical agitation.

A rather promising development is the anaerobic filter (AP) process. This system simply consists of a vertical filter bed filled with an inert support material such as gravel, rocks, coke, or some plastic media. Laboratory and pilot-plant experiments have shown that the AF process is suitable to treat various types of chiefly dissolved wastes with a very satisfactory treatment efficiency at hydraulic and organic loading rates. The SRT of the AF process is very satisfactory, which may beattributed to the gradual development of a highly settleable- more or less granular-sludge. This sludge is effectively entrapped in the packing.

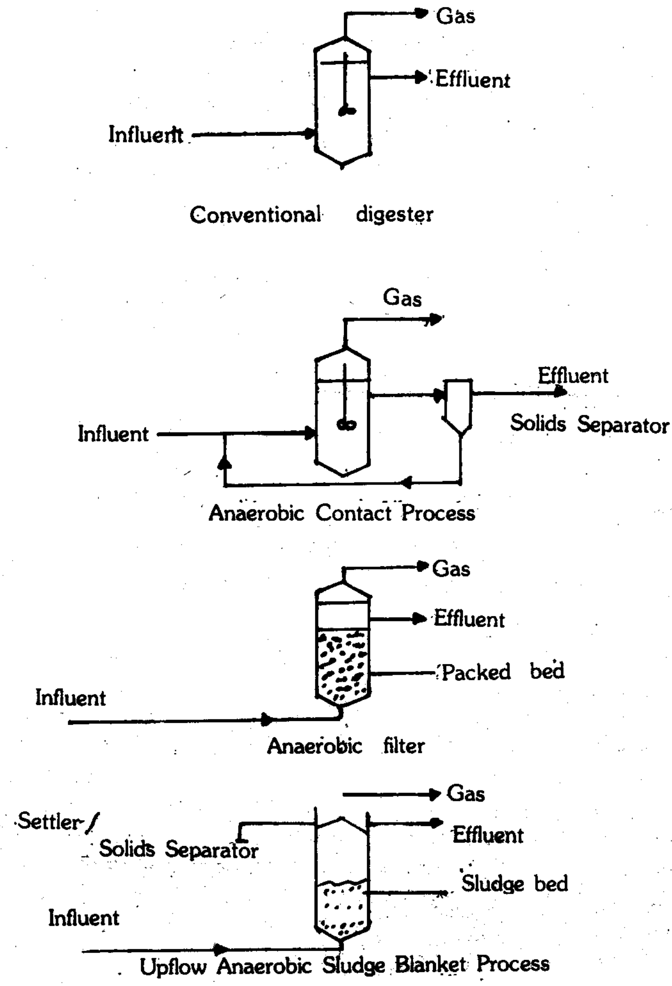

FIG. 1. Schematic diagrams of various anaerobic treatment processes.

UASB CONCEPT

In the UASB process of anaerobic treatment :

a) sludge recirculation and/or mechanical agitation are kept at a minimum or even completely omitted, and that-in-particular-.

b) the reactor is equipped in the upper part with a proper system for gas-solids separation. A schematic diagram of an UASB reactor is shown in Figure 1.

The basic ideas underlying the process are :

a) The anaerobic sludge obtains and maintains superior settling charactristics of chemical and physical conditions favourable to sludge flocculation and to the maintenance of a well flocculated sludge are provided.

b) A sludge blanket (bed) may be considered as a separate more or less-fluid phase with its own specific characteristics. A well-established sludge blanket frequently forms a rather stable phase, capable of with-standing relatively high mixing forces. The redispersion of the sludge in the liquid phase therefore may require a significant amount of mixing energy.

c) The washout of discrete sludge particles (flocs) released from the sludge blanket can be minimized by creating a quiescent zone within the reactor, enabling the sludge particles to flocculatem, to settle, and/or to be entrapped in a secondary sludge blanket (present in the settler compartment).

In FLUIDISED BED REACTORS the active biomass is present in the form of a bed of readily settleable aggregates. These aggregates consist of biomass grown on small, inert particles such as fine sand or alumina. A rapid & even flow of liquied is used to keep the particles in suspension. If the rate of resulting expansion is 10-25%, the reactor is termed fluidised, and if 10-15%, it is termed expanded bed.

Limitations of Reactors

In Contact Reactors difficulties are due to obtaining good settling and adequate mixing. Generally, upto 80% of the micro-organisms may settle, indicating that the hydraulic retention time cannot be less than one fifth of the minimum mass doubling time. The latter is usually 10 days or more. For many wastes, the settling efficiency is less than 80% and the minimum hydraulic residence times are correspondingly longer.

In Anaerobic Filters (AF) limitations are because of high cost of packing and accumulation of solids in the packing material, which may plug the reactor. The hard-to-digest suspended solids that settle readily interfere with the operation of reactor. In large reactors, an inadequate liquid distribution system may cause channeling and short circuiting.

Problems with the UASB reactor are usually associated with the development of the granular sludge. Inoculation with large amounts of granular sludge from a well functioning UASB can help.

In Fluidised Bed Reactors, performance depends very much on the evenness of the flow, and as a result, the system of liquid sistributio is critical. The capital cost of the flow distribution system and the pumps is high.

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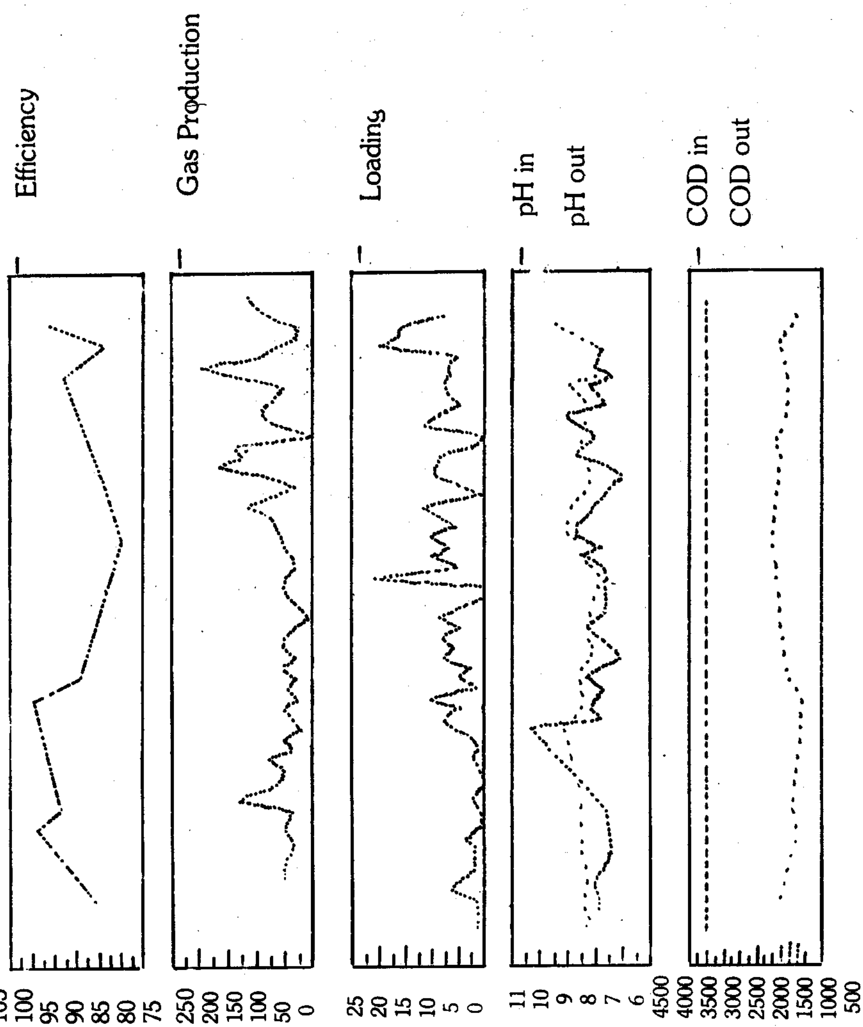

LABORATORY EXPERIMENTS
on Black Liquor from Agro Based Mill

At present the largest number of High Rate Anaerobic Reactors working successfully in the world on Industrial Wastes are UASBs.

The UASB concept has been extensively investigated in our laboratory with reactors varying in volume from ½ litre to 120 litres. The potential feasibility of the UASB concept has been demonstrated for anaerobic treatment for agro based pulp & paper mill.

These results are presented in the form of graphs. The following parameters are charted (fig 2.) Care was taken to simulate the actual working conditions as much as possible. The reactor was fed with varying pH and feed. At times the reactor was even shut down, as is the actual case, because of erratic power supply.

COD IN
COD OUT
pH IN
pH OUT
LOADING
GAS GENERATION
EFFICIENCY.

The efficiency of the Lab. reactor has a mean around 90%. An efficiency of 100% indicates that 100% of fraction biodegradable by anaerobic means has been biodegraded.

The loading has been substantial. Upto 20 kg COD/m^3.d reactor volume was loaded. But it appears that a safe design would be 12 to 15 kg COD/m^3.d reactor volume. This would imply that a 500 m^3 reactor for a 10 TPD mill, a 1000 m^3 reactor for a 20 TPD mill; and a 1500 m^3 reactor for a 30 TPD mill should be adequate. 90% reduction of BOD would be possible, thus saving substantially in energy costs, which would otherwise be required for airation in conventional ETP.

The methane generated could be burnt in boiler giving substantial benefit to the mill, by saving coal. A pay back period of 2-3 years can be anticipated.

SOME DATA FROM REFERENCES

Electricity required to destroy one ton COD

by Aerobic means..... 1100 Kwh

by Anaerobic means....15 Kwh

Conclusions:

It was found that the reactor could be controlled easily nd gave very encouraging results. Simple produres and ordinary training to Mill chemists would suffice to control UASB reactors. The potential benefits indicate that UASB could nullify the burden on the mill for Effluent Treatment Plants, day to day costs. Pilot Scale reactors are available for trials at Mill sites. Computer programme is also available for evolving optimum capacities & other parameters.

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