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THE PROBLEMS OF ANAEROBIC DIGESTION

Topliceanu Liliana
University of Bacau
Calea Marasesti Nr. 157, Bacau
Romania

ABSTRACT
In the last 30 years, a remarkable evolution has occurred in the attitude towards in-reactor digestion of solid wastes. The skepticism with respect to the feasibility has changed towards a general acceptance that various digester types are functioning at the full scale in a reliable way.
There are three principal types of anaerobic digesters: one-stage, two stage and batch systems. Most existing full-scale plants were designed with a single-stage reactor and reflect the relative newness of the technology. It can be expected that one-stage systems will continue to dominate the market, but the other projects are in a general improvement. The paper presents the type of anaerobic digesters and makes a comparison between them from biological, technical and environmental viewpoint.
Keywords:

1. INTRODUCTION

The anaerobic digestion has existed as a technology over 100 years. It gradually evolved, from an airtight vessel and a septic tank, to a temperature-controlled, completely mixed digester, and finally to a high rate reactor, containing a density of highly active biomass. The microbiology of methane digestion has been examined intensively in the last decades. It has been established that three physiological groups of bacteria are involved in the anaerobic conversion of organic materials to methane. The first group, of hydrolyzing and fermenting bacteria, converts complex organic materials to fatty acids, alcohols, carbon dioxide, ammonia and hydrogen. The second group of hydrogen producing acetogenic bacteria converts the products of the first group into hydrogen, carbon dioxide and acetic acid. The third group consists of methane forming bacteria, converting hydrogen and carbon dioxide or acetate to methane.

2. FACTORS OF ANAEROBIC DIGESTION

In contrast to aerobic degradation, which is mainly a single species phenomenon, anaerobic degradation proceeds as a sequence process, in which several sequent organisms are involved. Overall anaerobic conversion of complex substrates therefore requires the synergistic action of the micro-organisms involved. A factor of utmost importance, in the overall process, is the partial pressure of hydrogen and the thermodynamics linked to it.

Another factor of fundamental importance has been the identification of new methanogenic species, and the characterization of their physiological behaviour. Of particular interest was the determination of the substrate affinity constants of both hydrogenotrophic and acetotrophic methanogens. While the first exhibit quite high substrate affinities and remove hydrogen down to ppm levels, the second group appears as yet to contain species with only low substrate affinities. This limited substrate affinity has an important consequence for anaerobic wastewater treatment.

A technological advance of utmost importance in anaerobic digestion has been the development of methods to concentrate methanogenic biomass in the reactor, especially in very low solids concentration in the wastewater, 1 - 2%. Such higher concentration of biomass can be achieved by the principle of autoflocculation and gravity settling by attachment to a static carrier (anaerobic filter), and/or attachment to a mobile carrier (fluidized bed), especially

For insoluble organics, the major advance made during the past decade relates to solid state fermentation (SSF), also known as dry anaerobic composting. Currently, several successful technologies to digest particulate organics at high rates, in solid state fermenters, are available. Of particular significance is the fact that, with systems operating in the thermophilic range (50 - 60°C), not only high volumetric conversion rates are obtained, but also a stable and hygienic end product, humus. Interesting progress has also been made on direct anaerobic treatment of wastewaters at low temperatures (8 - 25°C). Reactors with granular sludge beds and with polyurethane carrier matrices have been shown to hold potential for direct treatment of domestic wastewaters.

Unit processes	**Reusable products**	**Standards or criteria**
PRE-TREATMENT - Magnetic separation - Size reduction (drum or shredder) - Pulping with gravity separation - Drum screening - Pasteurization DIGESTION - Hydrolysis - Methanogenesis - Biogas valorization	- Ferrous metals - Heavy inerts reused as construction material - Coarse fraction, plastics - Biogas - Electricity - Heat (steam	- Organic impurities - Comminution of paper, cardboard and bags - Organic impurities - Calorific value - Germs kill off - Norms nitrogen, sulfur - 150 - 300 kW.h_{elec}/ton - 250 - 500 kW.h_{heat}ton
POST-TREATMENT - Mechanical dewatering - Aerobic stabilization or Biological dewatering - Water treatment - Biological dewatering - Wet separation	- Compost - Water - Compost - Sand - Fibres (peat) - Sludge	- Load on water treatment - Norms soil amendments - Disposal norms - Norms soil amendments - Organic impurities - Norms potting media - Calorific value

Besides the advances reported above, several other developments are currently occurring in the anaerobic treatment of wastewaters. As for aerobic treatment, they are indicative of specific weak points of the technology involved. For instance, information is constantly increasing with regard to the competitiveness of methane producing bacteria (MPB), relative to sulphate reducing bacteria (SRB). The low energy levels of the substrates introduced, and the high biomass wash-out rates both, appear to favour MPB at the expense of SRB.

Anaerobic digestion is assumed to be more sensitive to toxicants than its aerobic counterpart. Though not a misconception, this assumption currently requires re-evaluation. Three main factors determine the capacity of a biological treatment system to cope with toxic and recalcitrant chemicals: the nature of the chemical conversions; the ecophysiology of the microorganisms involved; and process design and plant operation.

3. ANAEROBIC TREATMENT SYSTEMS FOR MUNICIPAL WASTEWATER

If anaerobic processes could be shown to treat dilute wastewater consistently and reliably, it would be a highly significant development in wastewater treatment. Since anaerobic fermentation results in a

lower cellular yield, less sludge is generated, and hence lower sludge handling costs would be possible. In addition, lower energy requirements would result, since aeration would not be necessary, and methane would be produced as a byproduct. In fact, the treatment of wastewater might be a net energy producer.
Originally, anaerobic treatment was the preferred process for domestic wastewater management. Imhoff modified the septic tank for wastewater treatment in Germany, and by 1933 the Imhoff tank was used by over 240 towns in Germany. In general, these early processes were poor for removal of soluble BOD but were successful in capturing solids. Thus the anaerobic processes were abandoned, in practice, for liquid municipal wastewater treatment, with the development of stricter effluent standards and, until the middle part of the 1970s, the anaerobic fermentation process was not considered practical for treating low strength wastewater (BOD<500 1000 mg/l). Some of this problems was resolved by the new generation of anaerobic reactors (the anaerobic fluidized bed, anaerobic filter, and upflow anaerobic sludge blanket processes).

3.1 Anaerobic Filter
There have been numerous reports on the development of the anflow process, an anaerobic filter type process, from lab to pilot demonstration scale (Genung 1980; 1987). At hydraulic retention times of 9 - 10 hours and a loading rate of 0.25 kg/m3 /day for both TSS and BOD, 80% TSS removal and 70% BOD removal were achieved. This degree of efficiency was maintained in cold weather (12°C water temperature) but the rate of solids accumulation in the reactor was higher, and methane production decreased. The primary mechanism for the initial removal of TSS (and consequently much of the BOD) appeared to be biophysical filtration, thereby explaining why removal efficiency was not affected by temperature. The concentration of entrapped solids increased continually throughout the study period, and Genung noted that a management plan to remove such solids periodically was necessary. There have been other lab scale evaluations of the anaerobic filter for domestic wastewater treatment with similar findings.

3.2 Anaerobic Extended and Fluidized Beds
Hickey and Switzenbaum (1988) reported on the development of the anaerobic expanded bed process, which was found to convert dilute organic wastes to methane at low temperatures and at high organic and hydraulic loading rates. This process was being evaluated in 1988, on a 50,000 litre per day pilot scale, consisting of an anaerobic expanded bed followed by post- treatment. Jeris (1987) reported on a two year experiment, testing two pilot scale anaerobic fluidized bed reactors, treating primary effluent. One reactor used sand as a carrier, the other granular activated carbon (GAC). Seeding experiments indicated that the GAC developed a biofilm more quickly and had more attached biomass. In addition, better BOD removal was observed with the GAC reactor. He noted that removal efficiencies were essentially independent of organic volumetric loading rates. Over a twelve month period in temperate climates, effluent total BOD5 values were consistently around 40 mg/l.
Research continues on the use of fluidized bed reactors for sewage treatment in Japan, in the "Biofocus - WT" project, which is organized by the Ministry of Construction. It is proposed that the high organic removal efficiency of the process can be attributed to its ability to detain and degrade particulate organics. Best performance was also obtained with GAC in both the bench and pilot scale reactors by Brown et al. (1985).

4. UASB STUDIES
The upflow anaerobic sludge blanket process (UASB) is by far the most widely studied reactor configuration for domestic wastewater treatment. Its primary use is for the treatment of higher strength industrial wastewaters, but it can be used for lower strength municipal wastewater - especially in tropical areas (Lettinga et al. 1984). At temperatures exceeding 12°C, COD removal efficiency was around 60% and was not greatly influenced by temperature, loading rates, or HRT. However, at temperatures below 12°C, removal efficiency was significantly lowered. In later studies (using granular sludge as seed material), it was concluded that conventional UASB technology was not attractive for treating very dilute and very septic sewage under cold climate conditions (de Man et al. 1988). The authors noted the importance of good feed inlet construction for obtaining better contact between the immobilized organisms and the influent wastewater. Better contact of organisms

and wastewater can be achieved by a) greater height/diameter ratio, and b) recirculation of the effluent, which results in an expanded granular sludge bed (EGSB). The EGSB reactors had better contact and showed improved removals of soluble pollutants, making the EGSB look more attractive for treating cold and low strength wastewaters, after primary settling. The lower upward liquid velocities in the UASB reactors resulted in better entrapment of the non-soluble pollutants. Thus it is possible to improve UASB performance by increasing the contact between the wastewater and the organisms.

Because of these temperature effects, the UASB process has been more frequently applied to tropical areas where wastewater temperatures are usually at least 20°C. Savelli-Gomes (1985) reported on efforts by the sanitation company of the state of Parana, Brazil in treating domestic wastes anaerobically, mainly for the production of biogas. Over 20 plants for small communities have been constructed, with various combinations of anaerobic processes: septic tanks, anaerobic filters, Imhoff tanks, and UASB reactors. Three conventional UASB reactors have been constructed (small full scale) for the treatment of domestic wastewater. At Pirai do Sul, domestic sewage, along with the municipal solid wastes, industrial and agricultural wastes were treated in a full scale UASB reactor system, which supplies biogas to 286 homes. The system was operating well and achieving good quality effluent.

5. CONCLUSIONS

Anaerobic digestion systems are well known and now widely used throughout the world. Production and usage of biogas has demonstrated their benefits from environmental and economical points of view. The factor most strongly influencing the economic merit of an AD facility is maximising the sales of all usable co-products. Advanced technology end-use applications can increase the economic value of biogas, but only after sufficient production scale has been achieved to significantly reduce the unit cost of ownership. The use of more sophisticated AD processes for industrial waste treatment will increase. AD can decompose some organic toxic and hazardous materials in co-digestion schemes and this potential will be realised. For the future, the driving forces for the use of AD will probably drift away from energy production. Organic stabilisation, pathogen reduction, and the production of a high-quality soil improver will be important reasons to use AD in developing countries. Energy savings in operation and minimal sludge production from AD versus aerobic treatment will become more important in energy and landfill deficient areas.

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