UPFLOW ANAEROBIC SLUDGE BLANKET (UASB) REACTOR IN WASTEWATER TREATMENT

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Summary

Under anaerobic conditions, organic pollutants in wastewater are degraded by microbes producing methane and carbon dioxide. The degradation process is effective compared to the more conventional aerobic processes and produces only 5-10% of sludge. This saves considerably on cost associated with the sludge disposal. Among anaerobic technologies, the most popular ones is the upflow anaerobic sludge blanket (UASB). In the UASB process, the waste to be treated is introduced in the bottom of the reactor. The wastewater flows upward through a sludge blanket composed of biologically formed granules or particles. Treatment occurs as the waste comes in contact with the granules. Among the main applications for UASB are in the beverage, brewery, food and tannery industries. Case studies of UASB applications in treatment of distillery spent wash, treatment of effluent from vegetable tannery and treatment of newsprint paper industry are given.

1. Introduction

Under anaerobic conditions, organic pollutants in wastewater are degraded by microbes producing methane and carbon dioxide. The degradation process is effective compared to the more conventional aerobic processes (Hulshoff Pol et al., 1998) and produces only 5-10% of sludge (Metcalf and Eddy, 1991). This saves considerably on cost associated with the sludge disposal. In addition, since it does not require aeration, anaerobic process also saves substantial amount of cost associated with aeration, including equipment, maintenance and energy consumption. Since the late 1960's, a number of high-rate anaerobic reactors have been introduced for wastewater treatment. Among them, the most popular ones is the upflow anaerobic sludge blanket (UASB) (Lettinga et al., 1980).

A comprehensive survey (Hulshoff Pol et al., 1998) of worldwide application of anaerobic wastewater treatment identified over 1229 full-scale plants. Japan led the world with 162 anaerobic industrial wastewater treatment plants, followed by Germany (115), Netherlands (91), USA (83) and India (79). Table 1 shows that the most common type of reactor design is UASB. With 793 plants, it accounted for 64.5% of the total number of reactors, (Hulshoff Pol et al., 1998). Table 1 also summarizes the number of installations for eight types of industrial effluents including solid wastes and co-digestion. Effluent from food industry, with 336 plants, was the most common, followed by brewery (207), sewage (159), distillery (136), pulp/paper (87), etc. Organic matters in the effluent of these industries are mostly easily-degradable carbohydrates, Fang and Liu (2001).

A: Reactor type		**B: Wastewater source**	
Reactor	Number	Wastewater	Number
UASB	793	Food	336
Anaerobic contactor	112	Beer	207
Anaerobic filter	104	Domestic	159
Anaerobic pond	66	Distilleries	136
IC	50	Pulp/paper	87
EGSB	50	Sugar	76
Hybrid	33	Solid waste	71
Fluidized bed	21	Chemicals	71
Total	1229	Manure co-digestion	*65*
		Beverage	*58*

UASB: upflow anaerobic sludge blanket
IC: internal circulation
EGSB: expanded granular sludge bed

Table 1: Reactors and wastewater sources in anaerobic treatment.

Fang and Liu (2001) conducted a survey based on installation by four leading international companies (Paques, Biothane, Enviroasia, ADI) and showed that 338 of the 773 anaerobic wastewater treatment plants were installed in tropical and subtropical regions. Table 2 shows that a total of 77 plants were installed in Brazil, followed by India (75), China (43), Mexico (22), Philippines (22), Taiwan (21), Thailand (14). Table 2 also summarises the number of UASB plants installed in the countries with the most anaerobic treatment plants and the typical application of these plants, Fang and Liu (2001). Among the main applications for UASB are in the beverage, brewery, food and tannery industries.

Industrial wastewater contributes a significant part of the total pollution. In India for example, of the total pollution contributed by industries, 40-45% of the total pollutants can be traced to the processing of industrial chemicals and nearly 40% of the total organic pollution to the food processing industry alone. Food products and other agrobased industries together contribute 65-70% of the total industrial wastewater in terms of organic load (Kansal et al., 1998). The industrial sectors like sugar mills, breweries, distilleries, food-processing industries, tanneries, and pulp and paper industries consume huge volume of water for its various processes and generate large volumes of wastewater with high organic loading rates (Kaul et al., 1994). UASB provides an important treatment process for industrial wastewater.

Country	Number	COD removal Ton-COD/d	UASB Number	Typical Application
Brazil	77	1046.2	59	brewery
India	75	3377.9	47	distillery, tannery
China	43	366.5	37	beverage, brewery, food
Mexico	22	413.4	12	beverage, coffee, brewery, food
Philippine	22	454.2	16	food, brewery, distillery, beverage
Taiwan	21	207.5	21	food, leachate, chemical, beverage, brewery
Thailand	14	552.5	12	alcohol, agro-industrial wastewater
Indonesia	10	31.8		
Colombia	9	146.3		
Israel	9	67.8		
Venezuela	9	264.1		
Malaysia	8	142.2		
Chile, South Africa	3 each			
Argentina, Vietnam	2 each			
Hong Kong, Guatemala, Malawi, Kenya, Mauritius, Nepal, Pakistan, Puerto Rico, Saudi Arabia, Singapore	1 each			
Total	338	7476.1		

Table 2 Anaerobic treatment plants in sub-tropical regions installed by four international companies.

2. UASB Reactor

Lettinga et al. (1980) reported that the UASB reactor operates as suspended growth system where microorganisms attach themselves to each other or to small particles of suspended matter to form agglomerates of highly settleable granules that forms an active sludge blanket at the bottom of the reactor. The gas formed causes sufficient agitation to keep the bed fully mixed. In the UASB process, the waste to be treated is introduced in the bottom of the reactor. The wastewater flows upward through a sludge blanket composed of biologically formed granules or particles. Treatment occurs as the waste comes in contact with the granules. The gas produced under anaerobic conditions cause internal circulation which helps in the formation and maintenance of the biological granules. Some of the gas produced within the sludge blanket becomes attached to the biological granules (Huishoff Pol et al., 1983). The free gas and the particles (with the attached gas) rise to the top of the reactor. The particles that rise to the surface strike the bottom of the degassing baffles which release attached gas bubbles. The degassed granules drop back to the surface of the sludge blanket. The gases released from the granules are captured in the gas collection domes located in the top of the reactor.

It should be recognized that besides the formation of sludge granules, erosion also takes place in the sludge bed under the influence of friction forces to which the sludge flocs are exposed in particular at high mixing intensities (Fang et al., 1993, Fang et al., 1995*)*. The sludge particles would gain sufficient mechanical strength when proper environmental conditions are maintained at the start up. Gas re-circulation provides mechanical agitation at the gas-liquid interface in the digester compartment and is useful to prevent an accumulation of biodegradable waste solids in the lower part of the reactor and/or to ensure a good contact between bacteria and the substrate even at low gas production rates or high hydraulic loading rates. Under proper conditions active anaerobic sludge can be preserved unfed for many months without deterioration (Lettinga and Stellema, 1974).

Liquid containing some residual solids and biological granules passes into a settling chamber where the residual solids are separated from the liquid. The separated solids fall back through the baffle system to the top of the sludge blanket.

The UASB process has several advantages over other anaerobic processes. It is simple to construct and operate and is able to tolerate high organic and hydraulic loading rates. The key feature of the UASB process that allows the use of high volumetric COD loadings compared to other anaerobic processes is the development of dense granulated sludge. This has made it possible for the UASB to enhance the quality and the development of sludge with high specific activity and superior settling properties (Lettinga et al., 1980, Li et al., 1995).

A comparison of fluidised bed reactor (FBR) and UASB reactor showed that the high rate FBR technology did have limited success, and this may be partly due to the practical problems of controlling the attachment of biofilms to the carrier material. On the other hand, the high rate UASB technology which relies on the growth of granular sludge and a three phase separator (gas-liquid- solid) has been a commercial success in over 500 installations treating a wide range of industrial effluents throughout the world. (Lettinga and Hulshoff Pol, 1991).

The UASB reactor concept resembles the upflow sludge blanket process except that sludge recirculation and/or mechanical agitation are kept at minimum or even completely omitted. A typical UASB plant design consists of a biological reaction zone and a sedimentation zone. The organic compounds in the influent are converted to CH_2 and CO_2 in the reaction zone as the flow passes upward through the bed of activated sludge. The gas and sludge is separated by the gas-solid-liquid separator device. In the UASB reactor, the substrate degradation occurs mainly in the lower part of the reactor due to the presence of a high concentration of active anaerobic sludge, effective mixing (due to the upward escape of the gas produced) of the incoming waste flow with the partially purified liquor present in the upper part of the reactor and occurrence of colloidal particles and other specific wastes, and the precipitation, sedimentation, and/or entrapment of such undissolved matter. In the UASB reactor, higher loading rates at low detention times could be applied as the result of the high settlability and presumably of the high specific activity of the granules of about 1-3 mm in size. Several studies have shown that the UASB concept is applicable even for highly diluted wastes (Pette et al., 1980; Yan et al., 1993; Lettinga et al., 1980) with appropriate modifications to cause the required turbulence. UASB process provides a suitable method to treat wastes with a high concentration of undissolved solids (Lettinga et al., 1979). The effect of the hydraulic loading rate (HLR) on the sludge retention is closely related to the agitation intensity in the sludge bed.

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