Indian J Environ Health. 2001 Apr;43(2):1-82.

Upflow anaerobic sludge blanket reactor--a review.

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Biological treatment of wastewater basically reduces the pollutant concentration through microbial coagulation and removal of non-settleable organic colloidal solids. Organic matter is biologically stabilized so that no further oxygen demand is exerted by it. The biological treatment requires contact of the biomass with the substrate. Various advances and improvements in anaerobic reactors to achieve variations in contact time and method of contact have resulted in development of in suspended growth systems, attached growth or fixed film systems or combinations thereof. Although anaerobic systems for waste treatment have been used since late 19th century, they were considered to have limited treatment efficiencies and were too slow to serve the needs of a quickly expanding wastewater volume, especially in industrialized and densely populated areas. At present aerobic treatment is the most commonly used process to reduce the organic pollution level of both domestic and industrial wastewaters. Aerobic techniques, such as activated sludge process, trickling filters, oxidation ponds and aerated lagoons, with more or less intense mixing devices, have been successfully installed for domestic wastewater as well as industrial wastewater treatment. Anaerobic digestion systems have undergone modifications in the last two decades, mainly as a result of the energy crisis. Major developments have been made with regard to anaerobic metabolism, physiological interactions among different microbial species, effects of toxic compounds and biomass accumulation. Recent developments however, have demonstrated that anaerobic processes might be an economically attractive alternative for the treatment of different types of industrial wastewaters and in (semi-) tropical areas also for domestic wastewaters. The anaerobic degradation of complex, particulate organic matter has been described as a multistep process of series and parallel reactions. It involves the decomposition of organic and inorganic matter in the absence of molecular oxygen. Complex polymeric materials such as polysaccharides, proteins, and lipids (fat and grease) are first hydrolyzed to soluble products by extracellular enzymes, secreted by microorganisms, so as to facilitate their transport or diffusion across the cell membrane. These relatively simple, soluble compounds are fermented or anaerobically oxidized, further to short-chain fatty acids, alcohols, carbon dioxide, hydrogen, and ammonia. The short-chain fatty acids (other than acetate) are converted to acetate, hydrogen gas, and carbon dioxide. Methanogenesis finally occurs from the reduction of carbon dioxide and acetate by hydrogen. The initial stage of anaerobic degradation, i.e. acid fermentation is essentially a constant BOD stage because the organic molecules are only rearranged. The first stage does not stabilize the organics in the waste. However this step is essential for the initiation of second stage methane fermentation as it converts the organic material to a form, usable by the methane producing bacteria. The second reaction is initiated when anaerobic methane forming bacteria act upon the short chain organic acids produced in the 1st stage. Here these acids undergo methane fermentation with carbon dioxide acting as hydrogen acceptor and getting reduced to methane. The methane formed, being insoluble in water, escapes from the system and can be tapped and used as an energy source. The production and subsequent escape of methane causes the stabilization of the organic material. The methane-producing bacteria consist of several different groups. Each group has the ability to ferment only specific compounds. Therefore, the bacterial consortia in a methane producing system should include a number of different groups. When the rate of bacterial growth is considered, then the retention time of the solids becomes important parameter. The acid fermentation stage is faster as compared to the methane fermentation stage. This means that a sudden increase in the easily degradable organics will result in increased acid production with subsequent accumulation of acids. This inhibits the methanogenesis step. Acclimatization of the microorganisms to a substrate has been reported to take more than five weeks. Sufficiently acclimated bacteria have shown greater stability towards stress-inducing events such as hydraulic overloads, fluctuations in temperature, fluctuations in volatile acid and ammonia concentrations etc. Several environmental factors can affect anaerobic digestion, by altering the parameters such as specific growth rate, decay rate, gas production, substrate utilization, start-up and response to changes in input. It has long been recognized that an anaerobic process is in many ways ideal for wastewater treatment and has following merits: A high degree of waste stabilization A low production of excess A low nutrient requirements No oxygen requirement Production of methane gas Anaerobic microorganisms, especially methanogens have a slow growth rate. At lower HRTs, the possibility of washout of biomass is more prominent. This makes it difficult to maintain the effective number of useful microorganisms in the system. To maintain the population of anaerobes, large reactor volumes or higher HRTs are required. This may ultimately provide longer SRTs upto 20 days for high rate systems. Thus, provision of larger reactor volumes or higher HRTs ultimately lead to higher capital cost. Among notable disadvantages, it has low synthesis/reaction rate hence long start up periods and difficulty in recovery from upset conditions. Special attention is, therefore, warranted towards, controlling the factors that affect process adversely; important among them being environmental factors such as temperature, pH and concentration of toxic substances. The conventional anaerobic treatment process consists of a reactor containing waste and biological solids (bacteria) responsible for the digestion process. Concentrated waste (usually sewage sludge) can be added continuously or periodically (semi-batch operation), where it is mixed with the contents of the reactor. Theoretically, the conventional digester is operated as a once-through, completely mixed, reactor. In this particular mode of operation the hydraulic retention time (HRT) is equal to the solids retention time (SRT). Basically, the required process efficiency is related to the sludge retention time (SRT), and hence longer SRT provided, results in satisfactory population (by reproduction) for further waste stabilization. By reducing the hydraulic retention time (HRT) in the conventional mode reactor, the quantity of biological solids within the reactor is also decreased as the solids escape with the effluent. The limiting HRT is reached when the bacteria are removed from the reactor faster than they can grow. Methanogenic bacteria are slow growers and are considered the rate-limiting component in the anaerobic digestion process. The first anaerobic process developed, which separated the SRT from the HRT was the anaerobic contact process. In 1963, Young and McCarty (1968) began work, which eventually led to the development of the anaerobic upflow filter (AF) process. The anaerobic filter represented a significant advance in anaerobic waste treatment, since the filter can trap and maintain a high concentration of biological solids. By trapping these solids, long SRT's could be obtained at large waste flows, necessary to anaerobically treat low strength wastes at nominal temperatures economically. Another anaerobic process which relies on the development of biomass on the surfaces of a media is an expanded bed upflow reactor. The primary concept of the process consists of passing wastewater up through a bed of inert sand sized particles at sufficient velocities to fluidize and partially expand the sand bed. One of the more interesting new processes is the upflow anaerobic sludge blanket process (UASB), which was developed by Lettinga and his co-workers in Holland in the early 1970's. The key to the process was the discovery that anaerobic sludge inherently has superior flocculation and settling characteristics, provided the physical and chemical conditions for sludge flocculation are favorable. When these conditions are met, a high solids retention time (at high HRT loadings) can be achieved, with separation of the gas from the sludge solids. The UASB reactor is one of the reactor types with high loading capacity. It differs from other processes by the simplicity of its design. UASB process is a combination of physical & biological processes. The main feature of physical process is separation of solids and gases from the liquid and that of biological process is degradation of decomposable organic matter under anaerobic conditions. No separate settler with sludge return pump is required, as in the anaerobic contact process. There is no loss of reactor volume through filter or carrier material, as in the case with the anaerobic filter and fixed film reactor types, and there is no need for high rate effluent recirculation and concomitant pumping energy, as in the case with fluidized bed reactor. Anaerobic sludge inherently possesses good settling properties, provided the sludge is not exposed to heavy mechanical agitation. For this reason mechanical mixing is generally omitted in UASB-reactors. At high organic loading rates, the biogas production guarantees sufficient contact between substrate and biomass. Regarding the dynamic behaviour of the water phase UASB reactor approaches the completely mixed reactor. For achieving the required sufficient contact between sludge and wastewater, the UASB-system relies on the agitation brought about by the natural gas production and on an even feed inlet distribution at the bottom of the reactor. (ABSTRACT TRUNCATED)

PMID: 12397675 [PubMed - indexed for MEDLINE]

Publication Types, MeSH Terms, Substances