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REVIEW ARTICLE

Sewage Treatment Using Upflow Anaerobic Sludge Blanket Reactor in India

Abdur Rahman Quaff[1*] Sisir Mondal[2], Ashish Tiwari[3]

1. Assistant Professor, Civil Engineering Department, NIT, Patna, India, Contact No: 91-9473440781
2. M.Tech Student, MNNIT, Allahabad, India
3. Research Scholar, MNNIT, Allahabad, India

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***Corresponding Author**

Abdur Rahman Quaff

Abstract

This paper describes a review on development of anaerobic process and technology, involved for the treatment of domestic wastewater. In recent year there has been a growing interest for anaerobic processes over the conventional waste treatment techniques. The potential of producing usable energy makes the anaerobic biological processes unique. This feature has led to considerable fundamental research on anaerobic treatment systems specially Upflow Anaerobic Sludge Blanket (UASB) reactor over past three decades. The available literatures on the treatment of sewage and the applications of UASB reactor in India are reviewed in this paper

Introduction

Water is a vital resource that is used, misused, and wasted in society. Once water has been used, it becomes wastewater, which has its own characteristics and impact on the environment. Domestic wastewater (sewage) generated in urban area is one of the most urgent issues as the urbanization trend continuous globally. For example it is estimated that the sewage generation in Chennai (one of the metro city of India) would be of the order of 800 MLD by the year 2021 while the treatment capacity at present is only 267 MLD (CPCB and MoEF, 2001). This requires nearly 3 times increase of capacity. Similarly, in Allahabad 213 MLD wastewater generated and the treatment capacity is only 89 MLD (29 MLD at Salori STP and 60 MLD at Naini STP (Source: Ganga Polution Control Unit, Jal Nigam, Allahabad). At present India produces about 29000 million liter of sewage per day (MLD). Given the pace of development, burgeoning population and ever-increasing urbanization, sewage generation is only going to increase further in coming days. There is a huge gap between sewage generation and sewage treatment in India. India has an installed capacity to treat only 6000 million liter of sewage per day in a total of 269 STPs. Of these 269 STPs in India, 38 are under construction. Often these STPs operate below their treatment capacity further leading to widen the gap between generation and treatment.

This scenario warrants an urgent need to develop technologies to treat huge volumes of wastewaters in shortest possible time frame. The under-management of sewage in many such urban areas presents same challenge. The accumulation of sewage is constant and unmanageable directly contributes to the contamination of locally available fresh water supplies. Additionally, the cumulative results of unmanaged domestic wastewater can have broad degenerative effects on both public and ecosystem health. This leads to the death of more than one million children per year in the world under age of five, due to diarrhea diseases (UN, 2007). Therefore, the challenge faced by urban environmental management is to treat the wastewater and to return the water and residual, back into the environment with the least possible damage to the environment. It has been recognized that there is a need to develop reliable technologies for the treatment of sewage in developing countries. Such treatment systems must fulfill many requirements, such as simple design, use of non-sophisticated equipment, high treatment efficiency, and low operating and capital costs. In addition, due to urbanization, the cost and availability of land is becoming a limiting factor, and “footprint size” is increasingly becoming important in the choice of a treatment system (Aiyuk et al., 2006; Gillberg et al., 2003).

Limitations with Conventional Aerobic Technology in Urban region

Most conventional wastewater treatment technology are activated sludge plant (ASP) which is based on aerobic in which energy requirement (oxygen has to be supplied) and a large volume of waste bacteria (sludge) is produced, this makes the processes complicated to control, and costly. Therefore, this is not the proper solution for developing countries. Second example is waste stabilization ponds (WSPs) which provides good levels of treatment including pathogens removal at low capital and particularly low O&M cost. The major disadvantage is that significant areas of land are needed for treatment. This is another hurdle of using a huge area of land for treatment of wastewater in the urban area especially in the colony. Due to scarcity of land in the urban area this treatment technology is not feasible.

Third example is Karnal technology which was developed by Central Soil Salinity Research Institute (CSSRI), Karnal in 1981. The objective of this technology is to use sewage for raising rapid growth trees, like Eucalyptus. It involves making of 2m wide shallow trenches at a distance of 3m from center to center. In between the trenches, 1m wide ridges are made so that the depth of the trench is 50cm from the top of the ridge. Sewage is filled into trenches and high growth trees like Eucalyptus are grown on ridges. A part of water from sewage is trans-evaporated by the trees, some of it evaporated and remaining is percolated into ground. The organic matter is sewage is taken care by soil bacteria. Limitation of this technology is that it is generally used in acidic soil. Eucalyptus plants keep the soil alkaline due to high input of calcium ions through the litter fall as well as high conversion to biocarbonates (mainly Sodium bicarbonates). The trickling filter system is also based on aerobic process that biodegrade organic matter and can also be used to achieve nitrification. The wastewater trickles through a circular bed of coarse stones or plastic material. A rotating distributor (a rotating pipe with several holes across it) evenly distributes the wastewater from above the bed. The microorganisms in the wastewater attach themselves to the bed (also known as the filter media), which is covered with bacteria. The bacteria break down the organic waste and remove pollutants from the wastewater. The trickling filter have certain limitation like under high organic loadings, the slime growths can be so prolific that they plug the void spaces between the rocks causing flooding and failure of the system. Other aerobic technology fluidized bed bioreactor in which organic matter and nitrogen can be removed simultaneously in one single reaction tank by intermittent aeration. In such bioreactor, return sludge is not required. By using inorganic immobilized carrier, microorganisms are maintained to a high concentration, thereby enabling efficient treatment with compact equipment. Excess microorganisms spontaneously exfoliate from the carrier and flow outside of the system

Anaerobic Technology as an Alternative to Aerobic Technology

Anaerobic technologies should be considered for sewage treatment as an alternative to aerobic technologies in most developing countries for a variety of reasons. Anaerobic treatment can be carried out with technically simple setups, at any scale, and at almost any place. It produces a small amount of excess, well stabilized sludge, and energy can be recovered in the form of biogas. The process can be carried out in both centralized and decentralized modes, and the latter application can lead to significant savings in investment costs of sewerage systems.

Anaerobic treatment technologies, as noted by McCarty (1982) were explored as early as 1881. Within the domain of anaerobic technology, a low-cost technology such as the Upflow Anaerobic Sludge Blanket (UASB) has shown considerable promise recently. It was developed in 1970 in Netherlands by Lettinga and his Co-workers. Since then, several full-scale plants have been put into operation and many more are presently under construction. In 2002, about 100 of UASB reactors were in use for domestic wastewater treatment systems, particularly in the developing countries (Foresti, 2002). At present, over 200 full-scale UASB plants are in operation for the treatment of both domestic and industrial wastewaters worldwide (Khalil et al., 2008).

UASB is a robust high-rate reactor system, generally without moving parts; reducing both capital and operating costs. In the UASB reactor the wastewater enters at the bottom of the reactor and flows upward through the sludge bed. During the flow, it passes through high concentration of biomass in the sludge bed where the organic matter is degraded. The organic carbon is converted to biogas (mainly methane and carbon dioxide) due to high concentration of microorganisms (low food to microorganism ratio) although small amount of biomass is also produced. Upward flow of liquid and rising gas bubbles through the sludge bed provide mixing which enhance wastewater-biomass contact. The syntrophic association between different microorganism lead to self agglomeration within the biomass. These dense near spherical agglomerates with high settling velocity are known as “granules”. In the granulated sludge bed, a high upflow velocity can be maintained because of higher settling velocity of the granulated sludge thereby reducing the treatment time (Hulshoff Pol et al., 2004; van Haandel and Lettinga, 1994). The cost involved in the operation and maintenance of UASB plants is less than 1% of capital cost per year. It has also been estimated that the annual operation and maintenance cost of the UASB plant is approximately 30 % of the ASP based plants (IWTC12 2008, Alexandria, Egypt1420).

The Expanded Granular Sludge Bed (EGSB) reactor is a modified version of the UASB reactor which works on the same principle. This technology was modified to incorporate higher superficial velocities (greater than 4 m/h) by providing a larger height to diameter ratio and with the use of effluent recirculation. The higher upflow velocities expand the bed, eliminate dead zones and lead to better wastewater/biomass contact (van der Last and Lettinga, 1992). On the other hand higher upflow velocity results in washout of fine biomass particles that typically form after prolonged at low loading rates (Aiyuk et al., 2004).

This UASB reactor technology already have been applied successfully for the treatment of a various types of wastewater, including low-strength wastewaters, particularly under tropical conditions (Banu et al., 2007; Tandukar et al., 2005; Aiyuk and Verstraete, 2004). The process is applied in many countries all over the world. Many places where living standards are high have very diluted domestic wastewater. In India most of the cities, contain COD of sewage in the range of 200 mg/ l to 400 mg/l or even lower, instead of 500 mg/l to 700 mg/l reported for successful operation of UASB reactor by various researchers (Aiyuk et al., 2006; Foresti, 2001; Lettinga, 2001).

UASB Reactor for Low Strength Wastewater Treatment in India

Experiences with UASB technology in India are progressive. In India, UASB was introduced for the sewage treatment during the Ganga Action Plan (GAP) in a bilateral co-operation between India and The Netherlands in 1985. First full-scale UASB reactor of size 5 MLD for the treatment of domestic wastewater was running since April 1989 at Kanpur (Seghezzo, 2004). Subsequently, in April 1994 another unit of size 36 MLD was installed in the same town to treat the wastewater of approximately 180 tanneries after dilution with domestic wastewater in the ratio of 1:3 (Haskoning Consulting Engineers and Architects, 1996a). After studying the performance of the demonstration plant (Kanpur) for a few years, a full scale UASB plant of 14 MLD with a polishing pond of HRT one day was constructed at Mirzapur for treating the domestic wastewater. The plant has been constructed as part of the Indo-Dutch Environmental and Sanitary Engineering project under the Ganga action plan. It has been in full operation since April 1994 (Haskoning Consulting Engineers and Architects, 1996b). In all the cases, COD removal was only 50-70% along with some reduction of sulfate (Seghezzo, 2004; Draaijer et al., 1992). A similar plant designed for 50 MLD was built in the city of Hyderabad, India (Tare et al., 1997). Now the time has changed and at present India is one of the leading countries in terms of the amount of sewage volume treated by the UASB process (Sato et al., 2007). It is reported that 80% of total UASB reactors installed all over the world for domestic wastewater treatment is in India (Khalil et al., 2008). It has been recognized as one of the most cost effective and suitable sewage treatment process considering the environmental requirements in India (Sato et al., 2007; Aiyuk et al., 2006). According to 2005-06 reports of Ministry of Environment and Forests (MoEF), about 23 UASB sewage treatment plants with total installed capacity of 985 MLD were in operation and about 20 were in the pipeline which were likely to be commissioned within next 3-4 years (Khalil et al., 2008). Among the large capacity plants under YAP, in all 28 STPs comprising 16 UASBs, 10 Waste Stabilization Ponds (WSPs) and 2 BIOFOR (Biological Aerated Filtration Process) technology STPs with aggregate capacity of 722 MLD were constructed (MoEF, 2005 and 2006). This reflected, UASBs accounted for an overwhelmingly high 83% of the total created capacity. Reports also cover the types and sizes of the localities where these plants were installed. The Central Pollution Control Board (CPCB) report (CUPS/61/2005-06) of the same period puts the total number of sewage treatment plant based on UASB technology at 30 in the Class-I cities (population of more than 100000) and 3 in the Class II towns (population between 50000 and 99000). The state of Haryana almost entirely opted for UASB technology where 10 out of the 11 large plants were based on this technology.

Conclusions

Sewage treatment is not a cheap proposition. Public bodies have to think twice before making substantial investments particularly in developing countries where environmental issues could not be given priority due to financial constraints. During the past three decades, several new sewage treatment technologies have been developed and are being adopted in many developing countries particularly in the South-East Asian region including India. Every technology has its pros & cons and therefore has to be applied in accordance to the local conditions.

Recent developments in the field of anaerobic treatment have proved that the anaerobic treatment processes specially UASB reactor are not restricted to the high strength wastewaters, but also they can successfully be applied to low strength domestic wastewaters. The ability of small, UASB systems may be suitable for increased use in the urban environment. Two main reasons behind the importance of Using UASB are: (1) generation of large volume of low-strength wastewaters, which are often disposed untreated due to high costs, and (2) the potential of stabilizing the organic wastes by producing valuable energy byproduct. Finally it may be concluded that, UASB reactor has been recognized as one of the most cost effective and suitable sewage treatment process considering the environmental requirements in India.

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