A Study on Up-flow Anaerobic Sludge Blanket (USAB) reactor as a promising technology for anaerobic waste water treatment

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***Abstract*:** Water is one of the most valuable natural resources in the world. Unfortunately, it is being rapidly contaminated and urgent measures need to be taken for avoid its damage. In many countries, wastewater is released directly to lakes and rivers without treatment, and environmentally and economically feasible methods for waste water treatment are needed for sustainable development. A large number of technologies have been developed to achieve pollutant removal from waste water. In the present study, emphasis has been given on the application of Up-flow Anaerobic Sludge Blanket (UASB) reactor for the anaerobic treatment of high pollutant concentration of Industrial waste water. In this review paper, the main characteristics of anaerobic sewage treatment are summarized, with special emphasis on the UASB reactor.

Keywords: *Anaerobic treatment, Sewage, Domestic waste water, UASB reactors*

1. Introduction

Anaerobic biological treatment of municipal sewage has many advantages over aerobic treatment, such as lower operational cost, higher chemical oxygen demand (COD) loading rate, lower excess sludge production and energy recovery in the form of methane[1]. Anaerobic treatment of domestic wastewater is not a new concept and from time immemorial septic tanks, soak pits, cesspool, etc. have been used. Since these systems can only partially treat the sewage and, the effluent still contains high concentration of organic matter, suspended solids and nutrients, the interest for sewage treatment switched over to aerobic treatment systems. Though, most of the above mentioned drawbacks are not associated with aerobic systems but high land area is needed which is very uneconomical in densely populated countries like India. Therefore, these mentioned drawbacks make the anaerobic systems suitable for rural areas and developing countries[2]. Moreover anaerobic treatment can produce energy by producing various gases like methane and syngas[3]. This makes anaerobic treatment as an attractive tool for waste water treatment and energy production.

2. UASB Reactor

In spite of their early introduction, the interest on anaerobic systems as the main biological step (secondary treatment) in wastewater treatment was scarce until the development of the UASB reactor in the early 70s[4]. The up flow anaerobic sludge blanket (UASB) reactor was developed by lettinga and co-workers, being initially largely applied in Holland. The process essentially consists of an up flow of wastewater through a dense sludge bed with high microbial activity. The solids profile in the reactor varies from very dense and granular particles with good settle ability close to the bottom (sludge bed) to a more dispersed and light sludge close to the top of the reactor (sludge blanket). Upflow Anaerobic Sludge Blanket (UASB) reactor is termed as a “High Rate Reactor” (Solid Retention Time>>High Retention Time) has been successfully used in the recent past to treat a variety of industrial as well as domestic waste waters. The biosolids inside the UASB reactor can either be in granular or flocculant form. Granulation of biosolids is an indication of successful startup of the process. The granular form of the sludge offers various engineering advantages over the flocculant form such as the high solid retention time due its excellent settling property, providing maximum microorganisms to space ratio and application of higher loading rates as compared to UASB reactor with flocculant sludge. Hence characteristics of the sludge developed are of vital importance for maximizing advantages of this reactor and affecting the process economy[5].

The principle of USAB process is exactly opposite to the principle of sedimentation. In this process, the upward velocity wastewater flow works contrary to settling velocity of suspended particles. The up flow velocity exceeds the setting and the net velocity of the particle is in direction of flow. As the particle height increases the up flow velocity decreases and the vector sum of velocities becomes zero and the particles stop at that height. At this point a particle is considered as “removed “ from the water and gets settled on settling compartment[6]. The second fundamental principle of the process is the presence of a gas and solids separation device, which is located in the upper part of the reactor. The main purpose of this device is the separation of the gases contained in the liquid mixture, so that zone favouring sedimentation is created in the upper part of the reactor.

Conversion of organic matter takes place in all reaction areas (bed and sludge blanket), and the mixing of the system is promoted by the upward flow of wastewater and gas bubbles. The wastewater enters at the bottom and the effluent leaves the reactor through an internal settling tank in the upper part of the reactor. A gas and solids separation device located below the settling tank guarantee optimal conditions for sedimentation of the particles that stray from the sludge blanket, allowing them to return to the digestion compartment instead of leaving the system. Although part of the lightest particles is lost together with the effluent, the average solids retention time in the reactor is maintained sufficiently high to sustain the growth of a dense mass of methane-forming microorganisms, in spite of the reduced hydraulic detention time. Schematic diagram of UASB reactor is shown in Figure 1.

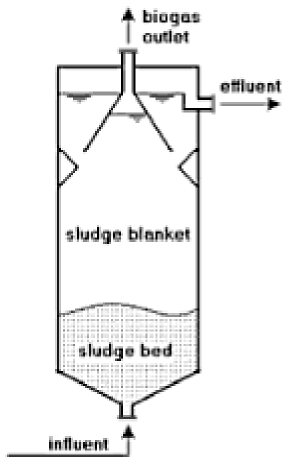

Figure 1: Schematic of UASB reactor

2.1 Design of UASB reactor

Generally, UASBs are considered where temperatures in the reactors will be above 20°C. Between 20 to 26°C, a solids retention time (SRT) of around 30 to 38 days in India gives a stabilized sludge for disposal on open sand beds. At equilibrium condition, the sludge withdrawn daily has to be equal to the sludge produced daily.

The sludge produced daily depends on the characteristics of the raw wastewater since it is the sum total of: (1) the new VSS produced as a result of BOD removal, the yield coefficient being assumed as 0.1 g VSS/g BOD removal, (2) the non- degradable residue of the VSS coming in the inflow assuming that 40 per cent of the VSS are degraded and residue is 60 per cent, and (3) ash received in the inflow namely TSS-VSS mg/l. the sum total of the above thee components gives the total solids produced per day and therefore the total sludge that must be withdrawn from the system at equilibrium conditions.

At steady state conditions:

(1)

SRT is generally kept between 30 to 50 days, or more depending on temperature. It is important to achieve the desired SRT value at the prevailing temperature. Another parameter is the hydraulic retention time (HRT) which is given by:

(2)

HRT is generally kept between 8 to 10 hrs.

The reactor volume has to be so chosen that the desired SRT value is achieved. This is done by solving for HRT from the SRT equation assuming: (1) depth of reactor, (2) the effective depth of the sludge blanket, and (3) the average concentration of sludge in the blanket.

Another parameter considered in design is the organic loading on the solids in the reactor. The full depth of reactor for treating low BOD municipal sewage is often kept at 4.5 to 5.0 m of which the sludge blanket itself may be 2.0 to 2.5 m depth. In this way, the organic loading remains within desired limits. For high BOD wastes, the depth of both the sludge blanket and reactor may have to be increased so that the organic loading on solids may be kept within the prescribed range.

2.2 Evaluation of methane and biogas production

The biogas production can be evaluated from the estimated influent COD load to the reactor that is covered into methane gas. In a simplified manner, the portion of COD converted into methane gas can be determined as follows:

(3)

Where, COD_{CH4} = COD load converted into methane (kg COD_{CH4} / d)

Q = average influent flow (m^3 / d)

S_o = influent COD concentration (kg COD_{CH4} / m^3)

S = effluent COD concentration (kg COD_{CH4} / m^3)

Y_{obs} = coefficient of solids production in the system, in terms of COD (0.11 to 0.23 $kgCOD_{sludge}$ / $kgCOD_{appl}$)

The methane mass (kg COD_{CH4} / d) can be converted into volumetric production (m^3 CH_4 / d)

Q_{CH4} = (4)

Where, Q_{CH4} = volumetric methane production (m^3 / d)

K (t) = correction factor for the operational temperature of the reactor (kg COD / m^3)

K (t) = (5)

Where, P = atmospheric pressure (1 atm)

K_{COD} = COD corresponding to one mole of CH_4 (64 gCOD / mol)

R = gas constant (0.08206 (atm * L) / (mol * K))

T = operational temperature of the reactor (°C)

Once the theoretical methane production is obtained, the total biogas production can be estimated from the expected methane content. For the treatment of domestic sewage, the methane fraction in the biogas usually ranges from 70 to 80%.

3. Conclusion

UASB upflow anaerobic sludge blanket process is ideally suited for treating industrial and domestic wastewater containing medium to high concentrations of soluble organics. This anaerobic process requires very little energy (no aeration) and by virtue of its biogas generation is, In fact, a net energy producer. Carbon is largely converted to methane and carbon dioxide, resulting in virtually very low sludge production. The UASB has a distinguished international reputation for being highly reliable and economical.

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