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UPFLOW ANAEROBIC SLUDGE BLANKET

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ABSTRACT

Anaerobic treatment is generally used around the world as a biological stage in both domestic and industrial wastewater-treatment plants. The two principal advantages of anaerobic over aerobic treatment are the production of biogas, which can be used as fuel, and the lower rate of biomass production, which results in lower maintenance costs for the plant. The upflow anaerobic sludge blanket (UASB) reactor is an attractive alternative for regions in warm climates since it works better under mesophilic conditions and it does not need any supporting structure for the development of microorganisms, which grow in the form of granules. An equation considering the layer degradation in the granule was required, since in the UASB reactor the microorganisms form granules. For this, a stationary mass balance within the granule was carried out and an expression for the reaction kinetics was then developed. The model for the granule takes into account the mass transport through the inactive film around the granule, the intraparticle diffusion, and the specific degradation rate. A simplified model was also developed considering the case in which the microorganisms are dispersed in the reactor and granules are not formed. The UASB reactor is then described as formed by many well-stimulated reactors in series. The model was tested using experimental results from the literature and the sensitivity of the processes to model parameters was also addressed. The models describe satisfactorily the degradation of layer along the height in the reactor; the major part of the substrate is degraded at the bottom of the reactor due to the high density of biomass present in that region. This type of model is a valuable tool to optimize the operation of the reactor and to predict its performance.

Index Terms: *Wastewater, anaerobic treatment, modelling, UASB reactor.*

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1. INTRODUCTION

The upflow anaerobic sludge blanket reactor (UASB) is a single tank process in an anaerobic centralised or decentralised industrial wastewater or blackwater treatment system achieving high deduction of organic pollutants. Wastewater enters the reactors from the bottom, and flow upward. A suspended sludge blanket filters and treats the wastewater as the wastewater flows through it. Bacteria living in the sludge break down organic matter by anaerobic digestion, transforming into biogas. Solid are also retained by a filtration effect of the blanket. The upflow regime and the motion of the gas bubbles allow mixing without mechanical assistance. Baffles at the top of the reactor permit gases to escape and prevent an outflow of the sludge blanket. As all aerobic treatment, UASB require a post-treatment to remove pathogens, but due to low removal of nutrients, the effluent water as well as the stabilised sludge can be used in agriculture.

In countries with a warm climate throughout the whole year, high wastewaters allow and favour an anaerobic treatment of the entire sewage flow, not only the sludge portion. Anaerobic treatments systems such as UASB do not require an energy consuming aeration system and can be constructed much simpler than aerobic treatments. They convert the organic matter into biogas, which can be recovered. The nutrients rich effluents can be used for agricultural irrigation. Sludge, even is partly stabilised (mineralised) and can be used as an organic soil fertiliser after composting or drying.

UASB reactors can treat all type of high-strength wastewater. It can be used at large-scale (e.g. agro industrial waste) or as decentralised treatment system for domestic wastewater; yet domestic treatment is still relatively new and not always successful as domestic wastewater generally lower strength.

1.1 Historical Background

Biological treatment of waste water 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. Biological treatment of waste water can be broadly classified into two type

1) Aerobic and
2) Anaerobic systems

The process that essentially requires the presence of molecular oxygen for metabolic activity of microorganisms is called aerobic process.

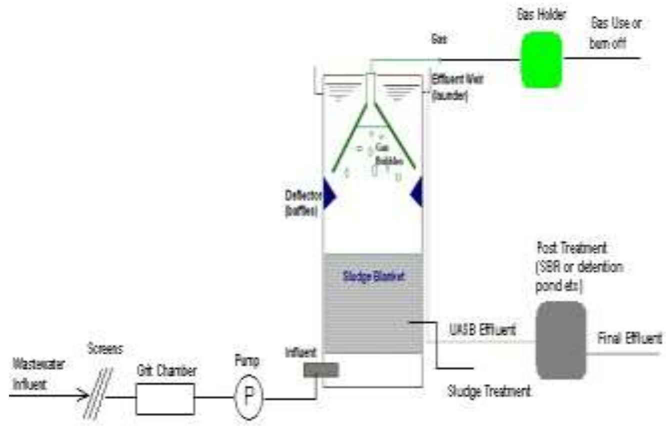
Aerobic treatment is the most commonly used process to reduce the organic pollution level of both domestic and industrial wastewater**.** Aerobic techniques**,** such as**,** activated sludge process, trickling filters, oxidation ponds and aerated lagoons have been successfully installed for domestic as well as industrial waste water treatments**.**

Although anaerobic system for waste treatment have been used **s**he late 19th century, they were considered to have limited treatment efficiencies and were too slow to serve the needs of a rapidly expanding waste water volume, especially, in industrialized and densely populated areas**.** However, recent developments have demonstrated that anaerobic processes are economically attractive for the merit of different types of industrial wastewaters and in semi-tropical areas also for domestic wastewaters pal and Dhagat, (2004)**.**

1.2 Treatment process

UASB reactor are constructed out of concrete or a another watertight material and can be designed in circular or rectangular way. Wastewater material is pumped from bottom into the reactor where influent suspended solids and bacterial activity and growth lead to the formation of sludge. The mud blanket is comprised of microbial granules (1 to 3 mm in diameter), i.e. small agglomerations of microorganisms that, because of their load, resist being washed in the upflow. The microorganisms in the sludge layer degrade organic compound. As a result, gases (methane and carbon dioxide i.e. biogas) are released. The rising bubbles mix the sludge without the assistance of any mechanical parts. Upstream velocity and settling speed of the sludge is in equilibrium and forms a locally rather stable, but suspended sludge blanket. Sloped wall deflect material that reaches the top of the tank downwards. The clarified effluent is extracted from top of the tank in an area above the sloped walls. A gas-liquid solids separator (GLSS) separates the gas from the treated wastewater and sludge.

After a several weeks of us, larger granules of sludge from which, in turn, act as filter for smaller particles as the effluent rises through the cushion of sludge. Because of the upflow regime, granule-forming organisms are preferentially accumulated as the other are washed out. Fortunately, these bacteria are also more efficient for biogas production than flocculated biomass.



Upflow Anaerobic Sludge Blanket (UASB) Reactor Process Flow Diagram

Fig-1: Upflow Anaerobic Sludge Blanket Reactor

2. Design Consideration

UASB reactor are made of concrete or another watertight material and can be designed in a circular or rectangular way. Critical elements for intend of UASB reactor are the effluent distribution system, the gas-solids separator, and the effluent withdrawal design. The gas that rises to the apex is collected in the gas collection domes and can be used as energy for cooking, heating or other, but scrubbing before use is required. If the biogas is changed to electricity, the heat produced as a by-product can be reused to heat the reactor, favouring anaerobic digestion.

To maintain the reactor well-mixed and allowing the formation of granulated a good contact of the active sludge blanket and the effluent sewage, it is critical that the effluent is equally distributed in the bottom before moving upwards. Besides these intend requirements, the main influencing parameters are pH, temperature, chemical oxygen demand (COD), volumetric COD loads, HRT and flow, upflow velocity, concentration of ammonia and start-up phase.

2.1 pH VALUE

The pH value needs to be between 6.3 to 7.85 to allow bacteria responsible for anaerobic digestion to grow. The pH value is also important because at high pH values, ammonia (NH_4^+) dissociates to NH3 which inhibits the growth of the methane producing bacteria.

2.2 Temperature

For an optimum growth of these bacteria and thus a optimal anaerobic digestion, temperature should lie between 35 to 38^{o}c. Bellow this range, the digestion decreases by about 11% for each 1^{o}c temperature decrease and bellow 15^{o}c process is no longer efficient although bacterial activity can still be noticed at temperature less than 10^{o}c.

2.3 COD Loads

Influent should have concentrations of above 250 mg COD/L as for lower rates, anaerobic digestion is not beneficial. Optimum influent concentrations are above 400 mg COD / L and an upper limit is not known.

2.4 Hydraulic Retention Time (HRT)

The HRT should not be less than 2 hour. Anaerobic microorganisms, especially methane producing bacteria, have slow growth rate. At lower HRT's the possibility of washout of biomass is more prominent. The optimal HRT generally lies within 2 to 20 hours.

2.5 Upflow Velocity

The upflow velocity in UASB is an main design parameter as the process plays with the balance of sedimentation and upflow. On one hand sludge should not be washed out the reactor, and the other hand, a minimum speed needs to be maintained to keep the blanket in suspension, and also for mixing. An upflow velocity of 0.7 to 1 m/h must be maintained to keep the sludge in suspension. Primary settling is usually not required before the UASB.

2.6 Cost Considerations

The significantly lower level of technology required by the UASB process in comparison with conventional advanced aerobic processes mean that they are also cheaper in construction and maintenance. Capital costs for construction can be estimated as low to medium and comparable to baffle reactors. Operation costs are low down, as usually no costs arise other than desludging costs and the operation of feeding pump.

2.7 Operation And Maintenance

The UASB is a centralised treatment technology that must be constructed, operated and maintained by professionals. A skilled operator is required to monitor the reactor and repair parts, e.g. pumps, in case of problems.

UASB reactor require several months to start up. The sludge not only needs to form but need to adapt to the characteristics of the specific wastewater. As domestic or municipal wastewater already contains the consumption of nutrients and micronutrients required for bacterial activity and growth, they are generally less problematic than industrial wastewaters.

To keep the blanket in proper position, the hydraulic load must correspond to the upstream velocity and must correspond to the organic load.

Sludge production is relatively low. Desludging is frequent and only excess sludge is removed every 2 to 3 years.

2.8 Advantages

a. High reduction of BOD
b. Can withstand high organic and hydraulic loading rates
c. Low sludge production
d. Biogas can be used for energy
e. No aeration system required (thus little energy consumption)
f. Effluents is rich in nutrients and can be used for irrigation
g. Low land demand can be constructed underground and with locally available material
h. Reduction of CH_4 and CO_2 emission.

2.6 Disadvantages

a. Required operation and maintenance by skilled personnel; difficult to maintain proper hydraulic condition
b. Treatments may be unstable with variable hydraulic and organic loads
c. Requires expert design and construction
d. Not adapted for cold regions.

2.9 Applicability

A UASB is not appropriate for small scale or rural communities without a constant water supply or electricity and skilled labour. It is particularly adapted for densely populated urban area as it has low land requirement. The technology is relatively simple to design and built, but developing the granulated sludge may take several month. The UASB reactor has the potentially produce higher quality effluent than septic tank and can do in a smaller reactor volume. UASB are not adopted for colder climates. Since the process typically removes 80 to 90% of COD.

3. CONCLUSION

The UASB reactor describes the substrate degradation, the microorganism concentration growth and the particle size distribution along the height in the reactor. This type of reactor is an attractive alternative for regions in hot climates since it works better under mesophilic conditions and it does not need any supporting structure for the development of microorganisms, which grow in the form of granules. The developed UASB reactor is transient and is based on mass balances for the substrate and microorganisms in the reactor. For the substrate, the process includes dispersion, degradation of the organic matter in the substrate. The reaction rate for the microorganisms includes the growth and decay of the microorganisms. The decompose takes into account the microorganism dying and the fraction of biomass that may be dragged into the effluent. However, the UASB reactor describes satisfactorily the degradation of substrate along the height in the reactor; the major part of the substrate is degraded at the bottom of the reactor due to the high density of biomass present in that region. The development of UASB reactor is useful tool in the development and design. It allows researchers to study the consequences for the reactor performance of different types of substrate, different inlet substrate concentration, different flow rates and different kinds of biomass.

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