Design and Working of a lab scale UASB reactor for treatment of Pharmaceutical Industry

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Abstract: The pharmaceutical industry under study has the main products like Penicillin, Erythromycin and its derivatives. The waste water, coming from these products is highly concentrated with B.O.D., C.O.D. and S.S. So for treatment of this highly concentrated waste water anaerobic treatment (UASB) is advisable. Based on the efficiency and adequacy study of the treatment plant, the average value of B.O.D., C.O.D. and S.S has been found. This paper covers the design of UASB (Upflow Anaerobic Sludge Blanket) from these average values. After preparing the biological culture, the start-up for the UASB reactor requires stable operation. The performance of the UASB model has been evaluated against the incoming COD values v/s the treated COD values and the volumetric loading rate. And the result of the batch activity test, cumulative gas production is analsized.

Keywords: Upflow Anaerobic Sludge Blanket, Biological Oxygen Demand, Chemical Oxygen Demand, Suspended Solids, volumetric loading rate.

INTRODUCTION:

Due to rapid industrialization and abrupt population growth excessive pressure is on different fresh water resources. The excessive utilization of water resources resulted in contamination of water resources may be due to different reasons, the most critical of which are city sewage and industrial waste discharge. Sewage contributes about 60% of the total pollution load in terms of biological oxygen demand. In the absence of any waste treatment , as is normally the case, the environmental damage costs to the society works out to be more than the financial costs to the industry.

A huge amount of water is required for different industrial processes, only a small fraction of the same is incorporated in their products and some is lost by evaporation, the rest find its way into the water courses as wastewater. Thus the industries join the municipalities to contribute to the "pollution" of the natural bodies of water. Because of such pollution much attention is given in India on the treatment plants before disposed in to the municipal sewers or in natural water bodies.

Industries are taking active steps to reduce resource consumption, waste generation and waste discharge through process improvements. Waste-water from industrial sources is made to undergo a series of treatment operation with the objective of eliminating or reducing objectionable substances present to an acceptable level. The objectives of treatment are

- To make water acceptable with regard to its appearance, clarity and odor.
- To remove excessive amount of suspended solids, organic and inorganic matters.

The important factors, which affect the planning for an industrial waste water treatment plant, are

1. Variation in load with the size and the process used
2. Variation in concentration of the pollutants
3. Seasonal and daily changes in amount of organic load depending on the product produced
4. Variation in toxic materials
5. They are often nutritionally unbalanced
6. They are complex and differ in composition and nature of pollutants.

The Indian Pharmaceutical Industry today is in the front of India's science- based industries with wide ranging capabilities in the complex field of drug manufacturing and technology. Such industries use both inorganic and organic materials, the latter being either of synthetic or of vegetable and animal origin. Antibiotics and vitamins are produced by the fermentation of fairly complex nutrient solutions of organic matter and inorganic salts, by fungi or bacteria.

There are main two products of this pharmaceutical industry.

- Penicillin and its derivatives.
- Erythromycin and its derivatives.

In the product of penicillin, molds of "Penicillium notatum-chrysegenum group" are cultured under submerged aerobic condition on a medium consisting of nitrogen source, peanut meal, mineral salts and lactose. After fermentation the mold mycelium is separated by filtration. The filtrate is then acidified to a suitable pH using acid, and the penicillin is removed by extracted with a buffered solution. The isolated penicillin is finally purified by extraction with an organic solvent.

Erythromycin is produced by selected strain of Sreptomyces Erythreus. The culture is first grown in the laboratory laboratory on a small scale and then transferred to germinator vessel for further growth, and then is transferred to fermentor. The fermentation medium mainly consists of sugar, soya grits, soya oil, precursor, calcium carbonate and inorganic salts. The fermented broth is then extracted in the Ethylene Dichloride (EDC) solvent to extract Erythromycin.

In the penicillin solvent recovery plant the high content of H_2SO_4 is used to maintain the pH of 2 to 3. Due to that high amount of sulphate is present in the penicillin waste water stream. The Ethylene Diachoride is used for recovery of erythromycin so EDC is present in erythromycin waste water stream. And these both the waste water streams are going to the effluent treatment plant after pretreatment. So there is a presence of high sulphate and high EDC create problem in the anaerobic treatment of these streams. As these streams are having high C.O.D and B.O.D as well as due to fluctuations in characteristics of these streams, they are anaerobically treated. Anaerobic processes unlike other biological waste treatment methods enjoy a covetable energy budget. It is only in recent years that the complex series of reactions implicating a wide variety of intermediates and the microbial consortia involved in the bacterial methenogenesis have been un-revealed. Better understanding of anaerobic process thus facilitated has led to the development of several novel reactor configurations. Also with increasing demand for energy, the process may become commercially viable as a source of energy (methane).

In these all the anaerobic treatments, the upflow anaerobic sludge blanket(UASB) reactor has received widespread acceptance and has been successfully used to treat a variety of industrial as well as domestic waste waters. The presence of active granulated and/or thick flocculent biomass is one of the key factors in the maintaining designed solid retention time for proper functioning of the UASB reactor. Aggregation of bacteria possessing different metabolic pathway is pivotal importance for the energetic and kinetics of the overall substrate conversion in granulation. The granular form of sludge offers various engineering advantages over flocculent form

Pretreatment:

The effluent from penicillin plant is collected in a receiving tank for homogenization and equalization. Effluent of erythromycin is mixed with penicillin effluent. After mixing these two effluents the pH will become nearer to neutral range. If the pH is not coming to its neutral range the lime is added. Then this effluent is passing throw the decanter where liquid and solid can be separated. Then the erythromycin and penicillin effluent is fed to buffer tank for the collection and then it goes to the UASB reactor.

PROCEDURE FOR CULTURE DEVELOPMENT

In a UASB reactor 500 gm of cow dung was added in 2500ml of tap water. Then 200gms of diammonium phosphate was added. The final pH in the reactor was maintained to 6.5-7.5. After putting the biomass in the reaction vessel the content were mixed. Then the sample was taken out which was recorded as a zero hour sample. Subsequently samples were taken after every 24 hours of interval. pH of reaction vessel was adjusted to 7.0 everyday.

The samples were analyzed for COD, VFA and biogas production every day. Biogas production was measured by liquid displacement method. When the maximum COD of the feed reduction was achieved and the VFA concentration reached to the minimum with maximum level of gas production. The biomass was then separated from the liquid by siphoning the liquid as much as possible.

Model Development:

The UASB reactor is considered in the model to be composed of two completely mixed reactors, namely, sludge bed, sludge blanket, and the third settling compartment. The inlet valve for the inflow of waste water is provided at the lower part of the model. From that inlet valve waste water flows in the upward direction and the microorganisms' concentration in the influent is considered as zero. When the waste water flows in the upward direction the sludge blankets are formed and the treated effluent comes out form the outlet valve. In the middle portion of the model the different sampling points are provided.

The model is designed based on the parameters which, measured in the lab for six months and then the average value of all the parameters are taken into consideration.

Developed Model Data

- Flow rate=5 lit/day
- COD=47600gm/m^3
- Temperature=30 0C
- Soluble COD=30900 gm/m^3
- Influent TSS concentration=17000 gm/m^3
- COD/TSS =2.72
- Effluent TSS concentration=5000gm/m^3
- Factor of safety=1.5

Dimension of Model:

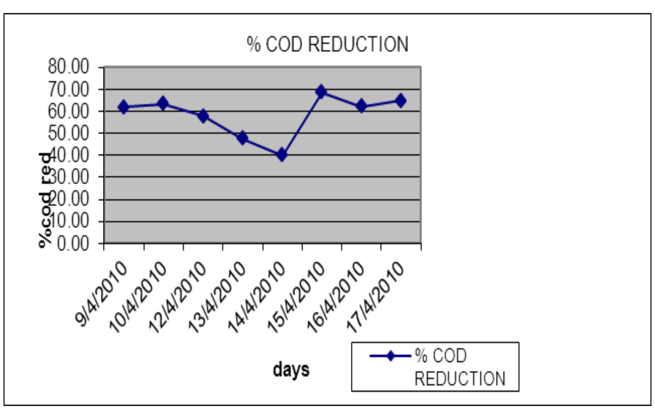
- Diameter of UASB reactor= 0.227m(0.200m provided)
- Total height of UASB reactor= 0.619m (0.600m provided)
- Height req. for liquid inside the reactor = 0.465m(0.5m provided)
- Height req. for gas collection= 0.099m(0.1m provided)
- Volume of the tank= 0.0188m^3
- Area of the tank= 0.04057m2

Evaluation for stable operation

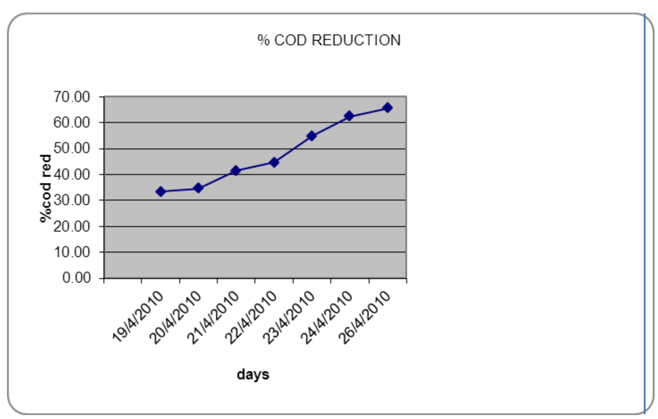
- The start-up period is considered as the period taken for stable operation to be achieved. Van der westhuizen and Pakkies (1992) indicated that stable operation is achieved when the measured parameters varied less than 10% after four reactor volume changes.
- The performance and start-up of the UASB model were evaluated against the incoming COD values v/s the treated COD values and the volumetric loading rate (VLR) that was applied. Stable operation was assumed when the COD removal efficiency did not vary significantly against the VLR applied and the COD removal efficiency did not vary more than 10%. The VLR is defined as the kg of COD fed to the reactor per cubic meter of total reactor volume per day.

Reduction in COD with different volumetric loading rate

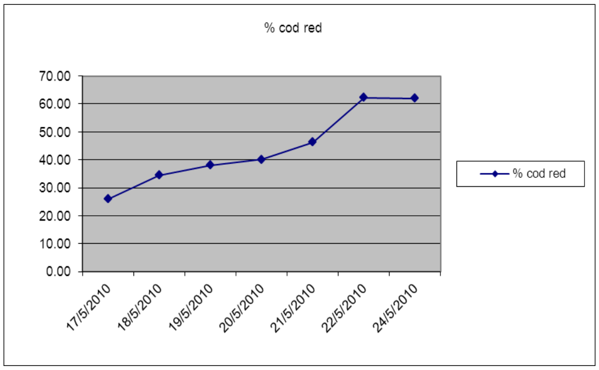
Graph No.1 for 0.5 kg/cod/m3/day loading rate



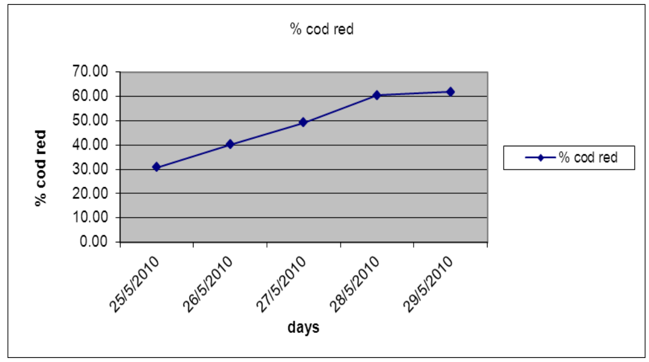
Graph No.2 for 1 kg/cod/m3/day loading rate



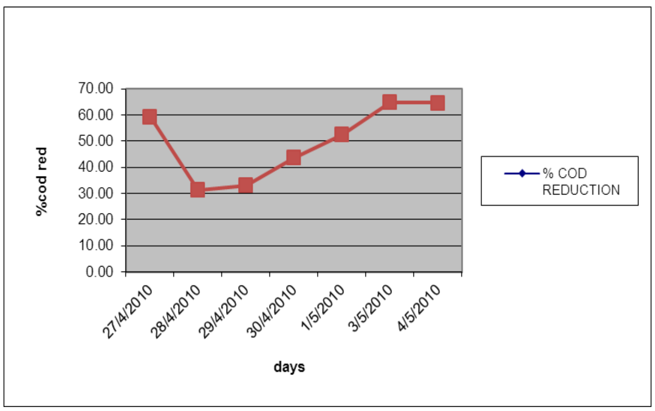
Graph No.3 for 2 kg/cod/m3/day loading rate



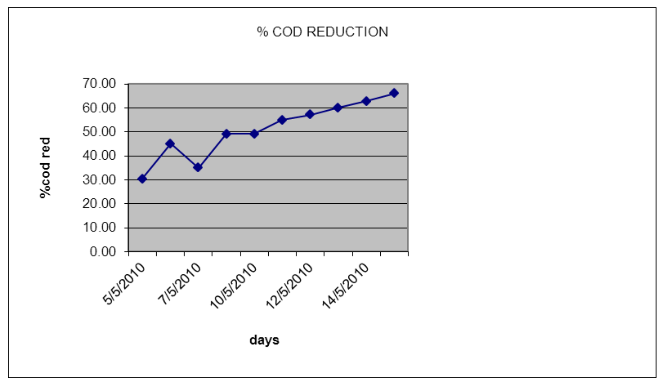
Graph No.4 for 3 kg/cod/m3/day loading rate



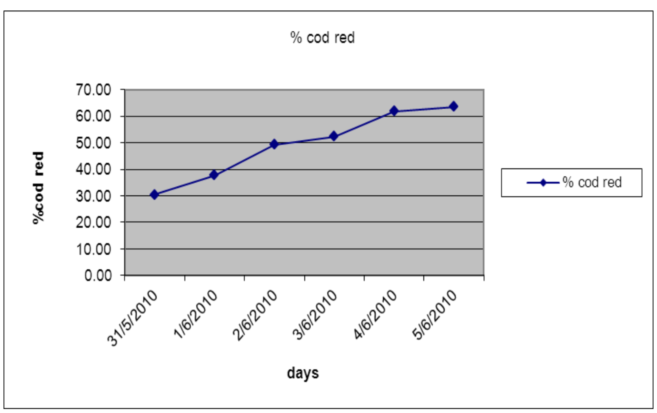
Graph No.5 for 4 kg/cod/m3/day loading rate



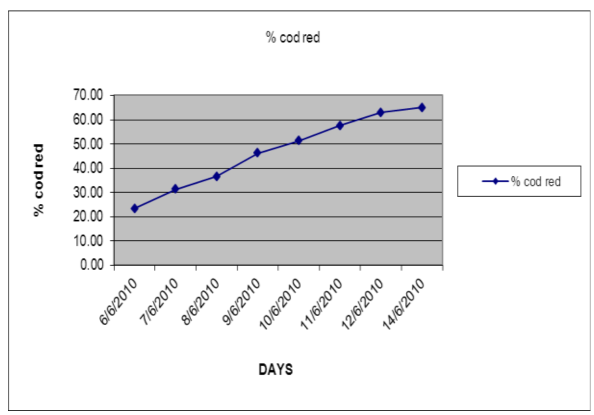
Graph No.6 FOR 5 kg/cod/m3/day loading rate



Graph No.7 FOR 6 kg/cod/m3/day loading rate



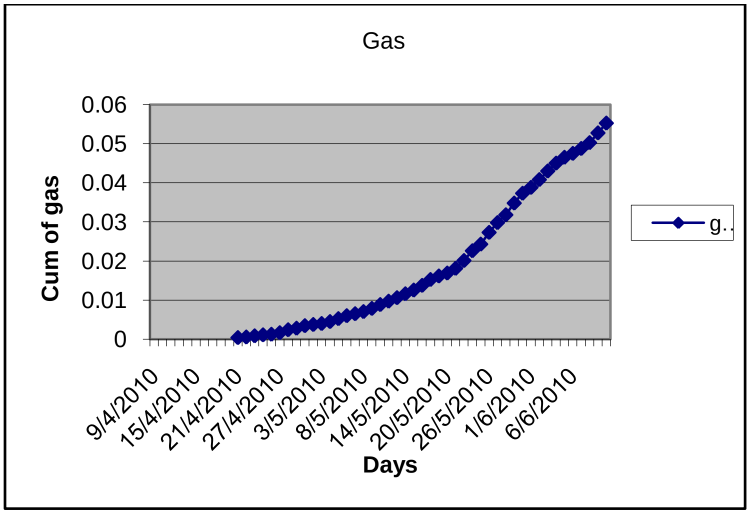
Graph No.8 FOR 7.55 kg/cod/m3/day loading rate



Gas Analysis:

The gas which is produced from the UASB reactor is analyzed in the laboratory. The result of this gas analysis is shown as under. And the cumulative gas production was analyzed by the water displacement method. And the volume of gas was analyzed.

Cumulative gas Production.



Report of Gas analysis:

Industry, location	Pharmaceutical industry.
Sampling method	Grab
Sample description	Biogas
Sampling point	Developed model of UASB

Sr. No	Parameters	units	Dates		
			Week 1	**Week 2**	**Week 3**
1	Methane(CH4)	%	63	55	65
2	Hydrogen sulphide(H2S)	ppm	10	79	50
3	Carbon monoxide(CO)	ppm	27	95	45
4	Power produced	Whr	1.43	1.25	1.47

Result and Conclusion:

Volumetric loading rate form 0.5 kgcod/m^3/d to 7.55 kgcod/m^3/d is applied to the system without decrease in the performance of the process (65% removal). The UASB technique is well suited for the pre-treated for the high strength pharmaceutical waste water. It must be noted that this is only when the process has been successfully started up and is in stable operation.

In order to achieve a successful startup it is recommended that the reactor was started up at a low loading rate of 0.5 kgcod/m^3/d. and the COD removal efficiency must be monitored. Once the COD removal efficiencies are above 60% and remain stable, then loading rate can be increased.

Once the plant has been successfully started up, fluctuations in the volumetric loading rate do not significantly affect the performance of the reactor. And after successfully started the reactor % COD removal is at 60% to 65%. And Volatile acid to alkalinity ratio is also maintained about 1. The pH is also coming to the neutral range of about to 7.

The volume of gas, which is measured through the water displacement method give about 0.002m^3. And in gas analysis about 65% Methane content is present, which gives a high calorific value of gas.

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