Review of Appling Anaerobic Fluidized Bed Reactor (AFBR) in Domestic Sewage treatment

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ABSTRACT

The purpose of this review is to present a study on Anaerobic Fluidized Bed Reactor (AFBR) in Domestic sewage treatment and how to use this type of treatment in several applications. So it is a simple description of the fluidized reactor, phenomena of fluidization actions, and the advantage of using the biomass as a source of power.

Keywords: Fluidized Bed Reactor, COD, Biological treatment, UASB.

Introduction: Fluidization is a mechanism in which, as gas is blown vertically upward into it, a bed of relatively dense solids particles takes on some of the characteristics of a fluid. The injection of gas (gas-solid systems) via a gas distributor from the bottom of a column containing solid particles will be causing the particles to extend and vibrate to offset the drag force exerted by the gas stream on them. When the velocity of the gas is raised, a stage arrives It is said that The weight of the particles matches the drag force. and that the bed is fluidized.

Every year, trillions of tons of CO2 gas escape into the atmosphere from the utilization of Fossil-based energy. Thus, the concentration of CO2 in the atmosphere must be decreased. To protect against the impact of human interaction with the environment to a lower degree. The estimation of fossil fuel resources raises additional challenges; There is a role for fossil fuels. Crucial position in the world's market for energy. However, stocks of this global energy supply will soon be depleted.

Fluidized Description: The most common fluidized reactor bed consists of a high-altitude bed whose lower portion, via a delivery mechanism, introduces water at a sufficiently high velocity to fluidize or extend the bed. In nature, anoxic and anaerobic systems are simpler. In comparison, aerobic systems include aeration. In the effluent recirculation line, this aeration is usually done, resulting in a 2-phase system: solid and liquid, as shown in Figure 1. The convenience of the injection of air through a recirculation line means that biofilm is not susceptible to abrasion, resulting in effluent with a low concentration of suspended solids.

The process is called "expanded bed" or "fluidized bed," depending on the expansion degree of the bed. With respect to the fixed bed reactor, the transition between the two systems varies between 50 to 100 percent expansion.

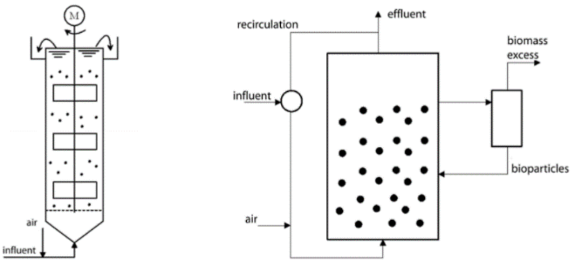

Fig. 1. Typical 2-phase fluidized bed reactor scheme. Plug flow (left) and pseudo-mixed flow reactor (depending on the recirculation rate).

Phenomena Description: As in Figure 2, A firm vertical bed materials backed up by a permeable or distributor layer with perforations is considered. The gas flow pattern throughout this bed is upward.

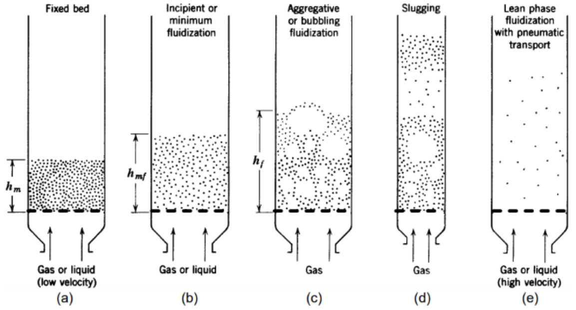

Fig. 2. Various kinds of contacting of a batch of solids by fluid.

During which the flow velocity reaches a specific level, although, the overall drag on the particles equals the bed's weight, and the particles will start to rise and slightly fluidize. While **Ac** is a cross-sectional area, **hs** is the depth of the beds set before the particles begin to rise, **h** is the height of the bed at any moment, and εs and ε are the porosities that coincide, of the, settled down and extended bed, respectively; then the mass of solids in the bed, Ws, is the mass of solids in the bed, Ws,

$$W_s = \rho_c A_c h_s \left(1-\varepsilon_s\right) = \rho_c A_c h \left(1-\varepsilon\right) \quad \text{………… eq. 1}$$

This equation depends on the theory that the mass of the bed covered entirely by solid particles remains constant regardless of the porosity of the bed. When the force of drag equals the force of gravity, the particles start rising, and the bed extends (i.e. when the height rises), thus leading to a rise in the porosity of the bed, as defined in (Eq. 1). This rise in bed porosity reduces the total drag til the entire gravitational force acting on solid particles is now balanced once more.

Biomass as a Fuel:

As an alternative fuel, the benefits of using biomass are described as follows:

1. Climate change mitigation, since biomass during photosynthesis CO2 is absorbed from the atmosphere and released into the biosphere following consumption.
2. Biomass has tremendous potential as a renewable energy source for both the developing world and the richer countries. The annual global biomass production is expected to be 146 billion metric tons, the major part of which is natural growing plants.
3. When energy production is based on biomass, emissions of SOX and NOX are reduced because it emits less sulfur and nitrogen than fossil fuels.
4. Biomass creation can assist the local economies, particularly if low-quality land that is unsuitable for food cultivation can be used.
5. Numerous forms of biomass differentiate it from other alternate sources of energy and numerous conversion procedures can be utilized to convert biomass into energy.

Studies in Fluidized Bed Reactor: Last and Lettinga (1992) explored the feasibility of anaerobic treatment of pre-settled domestic sewage using one-step UASB and EGSB systems for low-temperature conditions. In EGSB systems, viz., they recorded higher maximum removal efficiencies for soluble COD. Compared to 44 percent for UASB systems, 53 percent, while UASB systems are more effective for total COD, viz. 65 percent for EGSB devices, compared to 42 percent. Compared with traditional UASB reactors, the substantially improved interaction between sludge and wastewater in the EGSB system is claimed to be the major benefit of the EGSB compared to the UASB. In the EGSB systems, the high up-flow velocity applied scours the finely scattered SS and colloidal matter attached to the sludge, which will lead to a large increase in sludge activities due to the improvement in the transport of substrate through the sludge granules. The findings, however, clearly illustrate the inefficiency of the EGSB systems for SS elimination. High up-flow processes such as EGSB and Fluidized Bed (FB) reactors are not ideal for domestic sewage treatment unless they are combined with sufficient pre-settlement/treatment (Lettinga and Hulshoff Pol, 1991).

In 2008, Larisa Korsak conducted a thesis on the anaerobic treatment of wastewater at the UASB reactor. With the emphasis on the Upflow Anaerobic Sludge Blanket (UASB) reactor, the anaerobic treatment of wastewater has been studied. A model to explain the procedures of a UASB reactor was developed and an experimental study of the reactor was performed. In Nicaragua, anaerobic wastewater treatment systems have also been implemented. In order to link the study to wastewater, experimental work was carried out. A treatment situation in a developing country, Nicaragua. In order to evaluate the output of the treatment plants, the sludge's methanogenic activity from seven initially, anaerobic wastewater treatment plants were discussed.

The greatest operation was discovered in the sludge from in El Viejo area, the treatment plan, which means that this sludge will be used as a sludge inoculum in new plants for therapy. A very helpful experience has been gained in dealing with the industrial treatment plants' sludge. In the case of the wastewater treatment plant of the brewery, the inadequate concentrations of the wastewater treatment plant the cause of the unsatisfactory granular sludge was probably sulfide and iron forming. It was proposed to add these elements to the anaerobic reactor to the Treatment Plant Authorities. In the anaerobic unit, the hydraulic regime revisions can be made as well.

Farhana Tisa's research, in 2014, Study includes descriptive steps and estimates for the architecture of this unique FBR, It could make a difference in water treatment methods. Has articles for clear comprehension, this paper has been summarized. The computations are self-explanatory. and maybe used for another purpose. The basic aim of FBR design. The FBR efficiency is to be tested for phenolic water treatment (<200ppm). He followed a certain strategy that can be summarized as follows in figure 3:

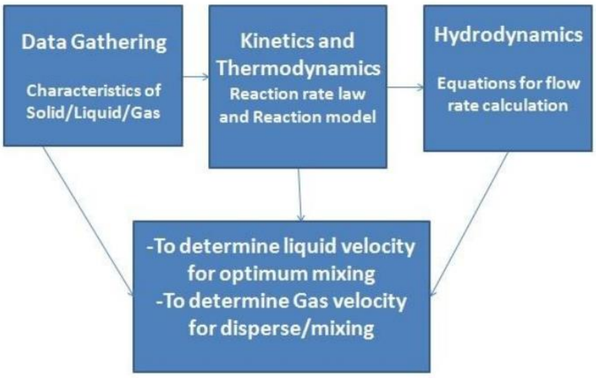

Fig. 3. Design steps proposed for the FBR design.

Work on simulations is underway to forecast the efficiency of the reactor. Geometric alterations (such as baffles) to see the impact on pollutant reduction, can be implemented as a prospective contribution. Economic viability, in addition, another aspect of the potential extension of this work could be analyzed.

A bio carrier made up of polypropylene of low density with a surface area of 524 mm^2, 870 $kg/m^3/m^3$ of density per particle and the fluidized bed reactor has been used in the wastewater treatment. Holdup trials for heights of the bed (0.20 m to 0.80 m) are conducted to estimate the situations for activity. The consequences of the height of the bed (0.60 m to 1.0 m), the time of hydraulic retention (6 h to 40 h) and velocity of surface gas (0.00106 m/s, 0.00159 m/s, 0.00212 m/s), concentrations (2.0 g/l to 7.50 g/l) on COD % reductions have been examined. The 0.8 m bed height gives the highest holdup and COD reductions. From the observations, the reduction of COD percentage has been observed to increase while the surface velocity of gas rises and reduces as the primary gas velocity raises. At the first level of 2.0 g/l and for gas on the surface, a COD reduction of 97.5 percent was accomplished. At an HRT of 40 hr, the speed is 0.00212 m/s. This study had been submitted by (K.Haribabua, V.Sivasubramanian, 2014). The bio carrier's needed minimum fluidization velocity from the experimental results was 0.00148 m/s, which would be lower than the material previously utilized for IFBR research. At a bed height of 0.8 m, a maximum gas holdup of 0.4849 was achieved with a surface gas velocity of 0.002548 m/s. The working conditions were 0.8m bed height and 0.00212 m/s surface gas velocity, an optimum COD reduction of 97.5 percent was achieved (figure 4 & 5).

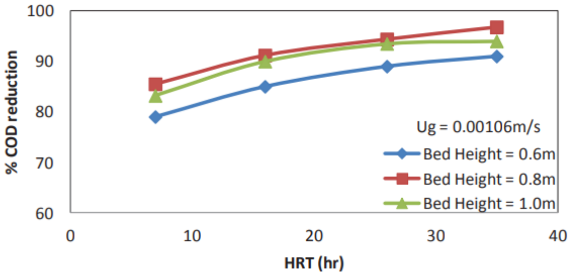

Fig 4. The influence of bed height on decrease %COD

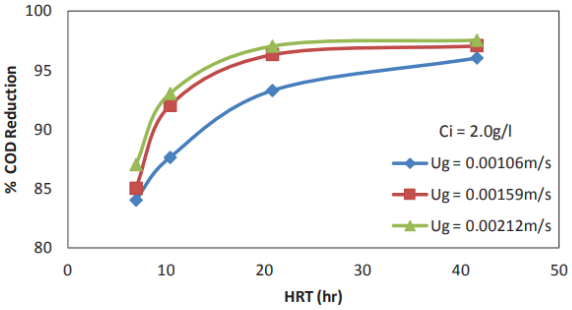

Fig 5. The influence of superficial gas velocity on % COD reduction

As the surface gas velocity and HRT increase, the percentage of COD reduction rises but is reduced as the primary level for a fixed bed thickness of 0.8 m increases. The performance of the device was high, with a new 870 kg/m^3 density bio carrier. It could be provided as an efficient treatment system for biological sewage.

Experimental research was performed (R. R. Souza, et al 2004) to assess the efficiency of a three-phase fluidized bed bioreactor (FBBR) (Fig. 6) utilized for milk sewage treatment. Three separate milk sewage substrate concentrations (462, 825, and 1473 mg O_2/L) were examined in this sample. When the same amount of supports particles are used, the outcomes show that the median of COD removal efficiency reduced as the organic load concentration in the substrate raised.

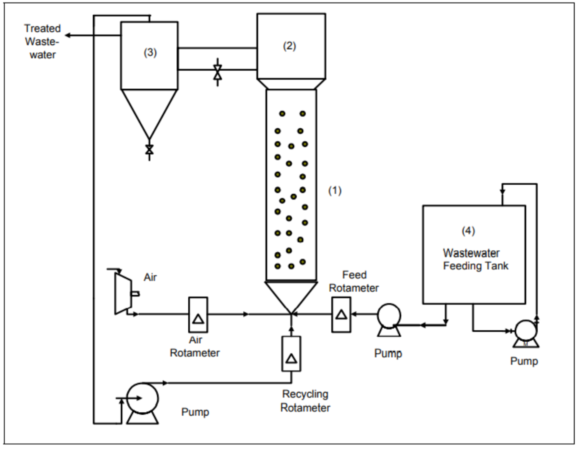

Fig 6. Effect of bed height on % COD reduction

The development of the FBBR microorganism was accompanied by the number of either liquid or support-attached biofilms including live cells. When it was utilized to breakdown higher organic loads, with most of the cells on the support, an increased number of viable cells was observed within the reactor. Because of the increased concentration of activated biomass, a comparatively high absolute degradation of high organic load wastewater was achieved. The findings presented in this study indicate (as shown in tables 1 & 2) that a three-phase fluidized bed bioreactor can degrade wastewater containing high organic loads, because hydrodynamics and operating circumstances, such as the supporting particles' surface area, are ensured to retain adequate sustainable biomass within the reactor. Viable biomass analytics showed that biomass that is attached to support particles is the key factor responsible for the degradation carried out, Despite some deterioration that occurs by suspended activated cells as the reactor was run in a blending scheme (high levels of recycling).

Table 1. Biofilm and live cells attach to supports particles.

Parameter	Experimental Phase		
	1	2B	3
Number of viable cells (× 10^9 CFU/g support)	0.49	1.79	2.84
Biofilm attached to support (mg/g of support)	4.31	6.44	6.35
% Viable cell in the biofilm	1.58	3.89	6.27

Table 2. The results of microorganisms suspended in the liquid.

Parameter	Experimental Phase		
	1	2B	3
Number of viable cells (× 10^{10} CFU/L)	6.9	22.5	57.5
COD of viable biomass (mg O_2/L)	13.7	44.6	113.9
COD inside FBBR (mg O_2/L)	150	440	755

When handling high-strength distillery wastewater, the efficiency of two laboratory-scale fluidized bed reactors with natural zeolite as support material was assessed. There have been two pairs of experimental studies. The effects of the organic loading rate (OLR), the degree of fluidization (FL), and the natural zeolite (DP) diameter of particles were evaluated in the first experimental collection. This experimental collection was performed at an OLR of 2.0 to 5.0 gram COD (chemical oxygen demand)/l d, 20 percent and 40 percent FL, and 0.2 to 0.5 mm (reactor 1) and 0.5 to 0.8 mm DP, respectively (reactor 2). OLR and FL were shown to have a minor effect on the removal of COD, they had a strong influence on the rate of methane production (N. Ferna´ndez et al, 2008). The results of the first experimental collection showed that OLR, FL, and DP did not substantially affect the pH of the effluent collected and the efficiency of COD removal. OLR and FL were, however, significantly affected by QM, but the impact of DP was not important (fig. 7).

The second experimental study revealed that even though OLR increased from 3.0 to 20 g COD/l d and influential pH was not regulated, pH values around the activity time remain within the optimal limit for methanogenic bacteria. Furthermore, no major variations in the effluent type of the reactors R-1 and R-2 were found, suggesting that DP did not affect the equilibrium of the process. With an improvement in OLR in both reactors, COD removal efficiency increased. The effect of the OLR on COD removal efficiency depending on the limit of OLR studied was calculated by a linear relationship. It was found that the impact of the influential concentration of the substrate on the rate of organic matter removal was satisfactorily defined by a first-order kinetic model. At a similar time, QM also raised with OLR on a linear basis as shown in fig. 8. Depending on the range of OLRs investigated, R-1 and R-2 had fairly comparable behavior, suggesting no influence of particle diameter on the output of the method.

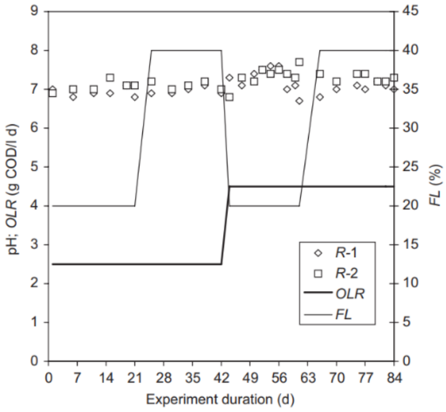

Fig 7. Effect of OLR, FL, and DP on the effluent pH in the 1st experimental set.

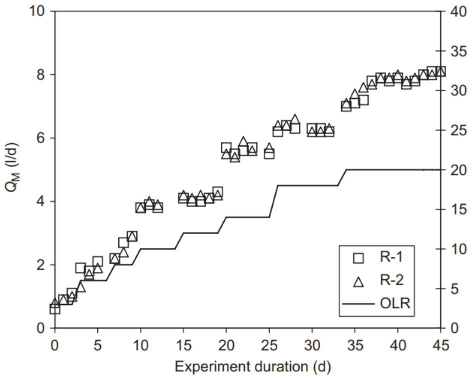

Fig 8. Impact of OLR, FL, and DP on the effluent pH in the first experiment set.

Conclusions:

1- The reduction of COD percentage has been observed to increase while the surface velocity of gas rises and reduces as the primary gas velocity raises.
2- As the surface gas velocity and HRT increase, the percentage of COD reduction rises but is reduced as the primary level for a fixed bed thickness of 0.8 m increases.
3- A three-phase fluidized bed bioreactor can degrade wastewater containing high organic loads, because hydrodynamics and operating circumstances, such as the supporting particles' surface area, are ensured to retain adequate sustainable biomass within the reactor.

4- OLR, FL, and DP did not substantially affect the pH of the effluent collected and the efficiency of COD removal. OLR and FL were, however, significantly affected by QM, but the impact of DP was not important.

5- Even though OLR increased from and influential pH was not regulated, pH values around the activity time remain within the optimal limit for methanogenic bacteria.

References:

1. Farhana Tisa, Abdul Aziz Abdul Raman, and Wan Mohd Ashri Wan Daud. Basic (2014) Design of a Fluidized Bed Reactor for Wastewater Treatment Using Fenton Oxidation. International Journal of Innovation, Management and Technology, Vol. 5, No. 2, April 2014.
2. K.Haribabua , V.Sivasubramanian (2014) . Treatment of Wastewater in Fluidized Bed Bioreactor Using Low Density Biosupport. Energy Procedia 50 (2014) 214 – 221.
3. R. R. Souza, et al . (2004). THE PERFORMANCE OF A THREE-PHASE FLUIDIZED BED REACTOR IN TREATMENT OF WASTEWATER WITH HIGH ORGANIC LOAD. Vol. 21, No. 02, pp. 219 - 227, April - June 2004.
4. N. Ferna´ndez, et al,(2014). Performance evaluation of an anaerobic fluidized bed reactor with natural zeolite as support material when treating high-strength distillery wastewater.
5. Alfredo Jácome Burgos, et al, (2014). FLUIDIZED BED SERIES: SECONDARY TREATMENTS. FS-BIO-007.
6. H. S. Fogler and L. F. Brown [Reactors, ACS Symposium Series, vol.168, p. 31 1981, H. S. Fogler ed.]
7. Abbas Abdulkareem Mahmood AL-Farraji (2017) PhD. Thesis , Chemical Engineering and Reactor Design of a Fluidised Bed Gasifier, School of Engineering-Cardiff University Cardiff, United Kingdom June 2017.
8. Demirbaş, "Biomass resource facilities and biomass conversion processing for fuels and chemicals," Energy Conversion and Management, vol. 42, pp. 1357-1378, 7// 2001.
9. Robinson, J. Rhodes, and D. Keith, "Assessment of potential carbon dioxide reductions due to biomass-coal cofiring in the United States," Environmental science & technology, vol. 37, pp. 5081-5089, 2003