Journal of Advances and Scholarly Researches in Allied Education
Vol. XV, Issue No. 2, (Special Issue) April-2018, ISSN 2230-7540

Design of a Fluidized Bed Bio Film Reactor for Wastewater Treatment

Satyam Sopori[1], Bagwan Mohamadazrodin[2], Ashpak Rafik Saudagar[3], Saudagar Ajharoodin L.[4], Prof. Neha Baghele[5]*

[1,2,3,4] UG Student, JSPM"s Imperial College of Engineering and Research, Wagholi, Pune

[5] Assistant Professor, JSPM"s Imperial College of Engineering and Research, Wagholi, Pune

Abstract – Fluidized Bed Biofilm Reactor (FBBR) can be an efficient alternative solution in advanced waste water treatment processes. FBBR process can reduce production of sludge in water treatment and also offers lower hydraulic retention time compared to other biological and chemical processes. The basic concept of the process consists of passing wastewater up through a packed bed of particles at a velocity sufficient to fluidize the particles. FBBR combines the best features of activated sludge and trickling filtration into one process. The design calculations have been done based on literature and some collective assumptions, from work it can be summarised that minimum fluidisation velocity for 50 MLD is 0.12m/sec. and the calculated Reynolds number show that, the fluidization to be a laminar fluidization.

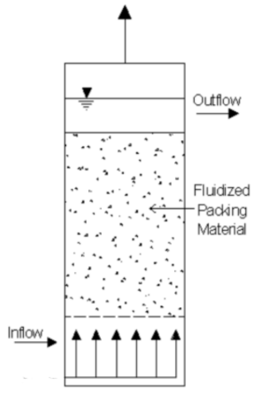
---------------------------------- X ----------------------------------

I. INTRODUCTION

Fluidized Bed Biofilm Reactor is widely applied in many industries for various applications recently. It has been found promising to use fluidized bed reactor for water treatment procedures. When the conventional treatment procedures lags behind to remove recalcitrant compounds in waste water (Abbas, et. al., 2014). However, Anaerobic oxidation pond are yet not without limitations. Studies reveal that an effective contacting device system can increase the potential of advanced oxidation systems.

Wastewater treatment involving physical unit operations and chemical and biological unit processes is carried out in vessels or tanks commonly known as "reactors" (Burghate1 & Ingole, 2014). The principle types of reactors used for the treatment of wastewater are – batch reactor, complete mix reactor (continuous flow stirred tank reactor – CSTR), plug flow reactor, complete mix reactors in series, packed bed reactor and fluidized bed reactor (Tisa, et. al., 2014). Waste water that is generated from many industries is highly recalcitrant and is threatening to environmental ecology and human lives. Biological and chemical processes have failed to convert the contaminants fully as, biological and chemical processes and degrade up to 60% of the recalcitrant components and in addition they require larger operation area and more chemical processes to reduce the sludge (Tisa, et. al., 2014). The Fluidized Bed Biofilm Reactor (FBBR) is a recent process innovation in wastewater treatment. Main application of the fluidized bed biofilm reactor is in the field of biological treatment of wastewater. Aerobic as well as anaerobic fluidized bed biofilm reactors (FBBRs) have received increasing attention for being an effective technology to treat water and wastewater. Its most important features are - the fixation of microorganisms on the surface of small-sized particles , leading to high content of active microorganisms and large surface area available for reaction with the liquid; the high flow rate (low residence time) which can be achieved , leading to high degree of mixing (decreased external mass transfer resistances) and to large reduction in size of the plant; and the removal of risk of clogging (Burghate1 & Ingole, 2014). The basic concept of the process consists of passing wastewater up through a packed bed of particles at a velocity sufficient to impart motion to or fluidize the particles. As the flow of the wastewater passes upward through the biological bed, very dense concentrations of organisms growing on the surface of the bed particles consume the biodegradable waste contaminants in the liquid.

Figure below is a schematic of the basic unit of the process, showing the entire fluidized bed reactor with the wastewater flowing upwards through the bed, fluidizing the particles in the liquid. Above the bed is a clear water zone wherein the particles separate from the liquid (Bayens, et. al., 1986).



II. GENERAL DESIGN STRATEGY FOR FBR

As the waste water to be treated will be from domastic sources so it may containt the domastic waste particles, so the design has to be done in such a way that it can accumulate all the process required for its treatement. The strategy of Fig. 1 therefore sidesteps for specific consideration. The different steps are discussed hereafter. To predict the behavior of a chemical reactor requires information on the hydrodynamics, stoichiometry, thermodynamics, heat and mass transfer, reaction rates, and lastly, flow or contacting pattern of materials in the reactor (Tisa, et. al., 2014).

Proposed design steps involved in the FBR design.

i. Data Gathering

ii. Kinetics and Themodynamics

iii. Hydrodynamic

iv. To Determine liquid velocity for optimum mixing

v. To determine Gas velocity for dispersion / mxing

III. DATA GATHERING

For the design of FBBR various properties of waste water has to be studied (Graham, et. al., 2006).

Characteristics	Range (g/capita-day)
BOD,5day,20°C	45 - 54
COD	1.5 - 1.9 x BOD
Total Solids	170 - 220
Suspended Solids	70 - 145
Grit 0.2 mm and above	5 - 15
Chlorides	4 - 8
Alkalinity ($CaCO_3$)	20 - 30

Typical Characteristics of waste water

A. Design Parameters

Design parameters mean the parameters to be considered for analysis and calculation in case of designing.. The Fluidized Bed reactor design should be made according to information available in the literature. The formulas for the design parameters are to be selected from vast literature available on researches in fluidized bed reactors and the study of fluidization profiles (Chou and Huang, 1999).

IV. DESIGN CALCULATIONS

1) Mean diameter of the bed particles

Fluidization characteristics depend on the composition of the mixture of different particle size at varying composition. Therefore, the bed voidage, minimum fluidization velocity and fixed bed pressure drop have dependence on the average particle diameter and mass fraction of the fines in the mixture (Tisa, et. al., 2014). Supposing if, we have particle size of dp1, dp2 and dp3 of same density and if, the composition of the mixture is a1:a2:a3, generally the equation for mean particle diameter would be

$$d_p = \frac{1}{\sum_{i=1}^{n}\left(\frac{f_1}{d_{p1}} + \frac{f_2}{d_{p2}} + \frac{f_3}{d_{p3}}\right)}$$

(*fi* indicates the fraction of *i*th component) (Tisa, et. al., 2014).

2) Sphericity of the particle

Sphericity is the measure of particles where, the particles are not ideal in both shape and roughness. It is the measure of a particle's non ideality in both shape and roughness. It is calculated by visualizing a sphere whose volume is equal to the particles and dividing the surface area of this sphere by the actually measured surface area of the particle (Tisa, et. al., 2014). The average sphericity for the particle mixture can be calculated by two different methods. First by the use of the correlation of Narsimhan for mono disperse particles. For binary and ternary mixtures the equation can be written as

$$\frac{1-\epsilon}{\emptyset_s} = 0.231 log\, d_{psm} + 1.417$$

where *dp,sm* is the average particle diameter in feet, is thevoid fraction and *φs* is the spericity (Tisa, et. al., 2014). In the second method theaverage sphericity has been calculated from the sphericitydata of irregular particles of dolomite of different sizesreported by Singh. The average sphericity can be taken as the mass mean sphericity and can be calculated using the following equation.

$$\emptyset_s = \sum_i x_{i\emptyset_{si}}$$

Normal measured values for a typical granular solid range from 0.5 to 1, with 0.6 being a choice for every round shaped particle (Tisa, et. al., 2014).

3) Void fraction of the bed

Before determining the minimum fluidization velocity of the reactor the void fraction, *emf of the bed particle should be* calculated. In fluidization upward liquid flow will fluidize the bed particles. Our fluid bed consists of sand. We will consider the mean particle diameter and mean sand density as the solid particle density for this calculation (Tisa, et. al., 2014). This *emf* is the void fraction at the point of the minimum fluidization.

$$\epsilon_{mf} = 0.578^{-0.7}\left(\frac{\mu^2}{\rho_f \acute{\eta} d_{p^3}}\right)$$

mf is the void fraction at minimum fluidization condition (Tisa, et. al., 2014).

μ is the viscosity of the fluid.

ρf is the density of fluid, *ρp* is the density of particle.

ρc is the density of catalyst. *s* is the void fraction when the bed is stable.

Hs is the height of bed when at stable condition.

Mv is the volumetric flow rate.

Df diameter of particle.

4) Minimum fluidization velocity, Umf

Most of the researches on FBR procedure have been practiced on a batch fluidized bed reactor. There can be various options of which fluidization procedure might be followed for waste water treatment. Conventional liquid–solid fluidization was studied intensively during the fifties. For pollutant treatment procedure the hydrodynamics of liquid-solid fluidization and liquid-solid-gas fluidization can bring the solution for design purpose. It has been considered that liquid–solid fluidization is a uniformly dispersed homogeneous fluidization, with or without external particle (Tisa, et. al., 2014).

Minimum fluidization velocity is for fluidizing the bed particles from the bed. It is the velocity required to begin the fluidization at which the weight of particles gravitational force equals the drag on the particles from the rising gas (Tisa, et. al., 2014).

$$U_{mf} = 7.90 \times 10^{-3} d_p^{1.82} (\rho_s - \rho_f)^{0.94} \mu_f^{-0.88}$$

5) Maximum fluidization velocity, Uf and terminal settling velocity, Ut

If gas or liquid velocity is increased to a sufficient limit, that the drag on every particle will surpass the gravitational force on the particles. This velocity if called Maximum fluidization velocity. Maximum fluidization is important parameter to know for avoiding particle entrainment. The operating fluidization velocity depends on the maximum fluidization velocity too (Tisa, et. al., 2014).

$$U_f = \left(\frac{1.78 \times 10^{-3} \times \acute{\eta}^2}{\rho_f \times \mu}\right)^{1/3} \times d_p$$

$$U_t = \left(\frac{4 g d_p (\rho_f - \rho_p)}{3 \rho_f C_D}\right)^{1/2}$$

V. RESULT

Conventional formula for the calculation of the volume (*V*) and cross sectional area (*Ac*) of a cylinder was used. The calculated results for our featured FBR are summarized below in Table

Table : Obtained Results for Final Design

Design parameter	Calculated result
Volume of the reactor, *V*	15.78m^3
Cross sectional area, *Ac*	5.260m^2
Reynolds number, *Re*	173
Void fraction∈, *mf*	0.59893
Minimum fluidization velocity, *Umf*	0.12m/sec

VI. CONCLUSION

The research contains descriptive steps and calculation for designing this particular FBR which is a potential contribution to water treatment technologies. Calculations are self-explaining and can be followed for other specific FBR design purpose. The performance of the FBR is to be evaluated for treatment of phenolic water (<200ppm). Simulation work is on-going to predict the performance inside the reactor as well.

REFERENCES

A. E. Oluleye, A. A. Ogungbemi, and C. O. Anyaeche : "Design and Fabrication of a Low Cost Fluidized Bed Reactor," *Innov. Sys. Design*

Abbas H. Sulaymon, Ahmed A. Mohammed, Tariq J. Al-Musawi (2014). "Predicting the Minimum Fluidization Velocity of Algal Biomass Bed"

Abhishek Sao, Omprakash Sahu (2014). "Comparative Study of Packed Bed Reactor and Fluidized Bed Reactor for the Production of Propylene Oxide" *International Journal of Scientific Research in Chemical Engineering, 1(1), pp. 1-8, 2014* Available online at *http://www.ijsrpub.com/ijsrce ISSN: 2345-6787; ©2014 IJSRPUb*

C.-C. Su et al. (2011). "Effect of operating parameters on decolorization and COD removal of three reactive dyes by Fenton's reagent using fluidized-bed reactor," *Desalination*, vol. 278, no. 1-3, pp. 211-218.

D.-H. Lee (2000). "Hydrodynamic Transition from Fixed to Fully Fluidized Beds for Three-Phase Inverse Fluidization," *Korean J. Chem. Eng.,* vol. 17, no. 6, pp. 684-690.

Doyce Tesoro Martinez , Tomas U. Ganiron Jr. and Harold S. Taylor "Use of Fludized Bed Technology in Solid Waste management"

Farhana Tisa, Abdul Aziz Abdul Raman, and Wan Mohd Ashri Wan Daud (2014). "Basic 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*

G. Narsimhan (1965). "On a generalized expression for prediction of minimum fluidization velocity," vol. 11, no. 3, pp. 550–554.

H. Gulsen and M. Turan (2004). "Treatment of Sanitary Landfill Leachate Using a Combined Anaerobic Fluidized Bed Reactor and Fenton's Oxidation," *Environmental Engineering Science*, vol. 21, no. 5.

H. Jena, G. Roy, and K. Biswal (2008). "Studies on pressure drop and minimum fluidization velocity of gas–solid fluidization of homogeneous well-mixed ternary mixtures in un-promoted and promoted square bed," *Chemical Engineering Journal*, vol. 145, no. 1, pp. 16-24.

H. M. Jena, G. K. Roy, and B. C. Meikap (2009). "Hydrodynamics of a gas–liquid–solid fluidized bed with hollow cylindrical particles," *Chemical Engineering and Processing: Process Intensification*, vol. 48, no. 1, pp. 279-287.

J. Bayens et al. (1986). *Solids mixing Gas fluidisation technology*, 1st ed., New York, U.S.A.: Jhon Wiley & Sons Ltd, 1986, pp. 97-122.

J. F. Richardson and W. N. Zaki (1954). "The sedimentation of a suspension of uniform spheres under conditions of viscous flow," *Chemical Engineering Science*, vol. 3, no. 2, pp. 65–73.

J.-P. Zhang, N. Epstein, and J. R. Grace (1998). "Minimum fluidization velocities for gas-liquid-solid three-phase systems," *Powder Technology*, pp. 113-118.

K. Mooson et. al. (1992). "Magneto fluidized G / L / S systems," *Chem. Eng. Sci.*, vol. 47, no.13–14, pp. 3467–3474.

L. Antoni et. al. (1986). "Improved equation for the calculation of minimum fluidization velocity," *Ind. Eng. Chem. Process Des. Dev*, vol. 25, pp. 426-429.

L. J. Graham, J. E. Atwater, and G. N. Jovanovic (2006). "Chlorophenol dehalogenation in a magnetically stabilized fluidized bed reactor," *AIChE Journal*, vol. 52, no. 3, pp. 1083-1093.

M. de Luna et al. (2013). "Kinetics of acetaminophen degradation by Fenton oxidation in a fluidized-bed reactor," *Chemosphere*, vol. 90, no. 4, pp. 1444-1448.

M. Lim et al. (2008). "Fluidized-bed photocatalytic degradation of airborne styrene," *Catalysis Today*, vol. 131, no. 1-4, pp. 548-552.

P. Bourgeois and P. Grenier (1968). "The ratio of terminal velocity to minimum fluidizing velocity for spherical particles," pp. 325–328.

R. K. Singh (1997). "Studies on certain aspects of gas solid fluidization in non-cylindrical conduits," PhD. Thesis, Dept. Chemical Eng., Sambalpur Univ., India.

S. Chou and C. Huang (1999). "Effect of Fe2+ on Catalytic oxidation in a Fluidized Bed Reactor," *Chemosphere*, vol. 39, no. 12, pp. 1997-2000.

S. Chou et al. (2004). "Factors influencing the preparation of supported iron oxide in fluidized-bed crystallization," *Chemosphere*, vol. 54, no. 7, pp. 859-66.

S. Choudhury and A. Sahoo: "Waste water treatment by inverse fluidization process: an overview" Choudhury et al., *International Journal of Advanced Engineering Technology , E-ISSN 0976-3945*

S. P. Burghate1, Dr. N. W. Ingole (2014). "Fluidized Bed Biofilm Reactor – A Novel Wastewater Treatment Reactor" *ISSN 2249–9695*

Sobrino Fernández, Celia "Experimental study of a bubbling fluidized bed with a rotating distributor" *http://e-archivo.uc3m.es*

W. Liang et. al. (1996). "Flow characteristics of the liquid–solid circulating fluidized bed," *Powder Technology*, vol. 90, pp. 95-102.

W. Nam, J. Kim, and G. Han (2001). "Photocatalytic oxidation of methyl orange in a three-phase fluidized bed reactor*," Chemosphere*, vol. 47, pp. 1019-1024.

X. L.Yang, G. Wild, and J. P. Euzen (1993). "Study of Liquid Retention in Fixed-bed Reactors with Upward Flow of Gas and Liquid," *Int. Chem. Eng,* vol. 33, pp. 72–84.

Y. J. Shih, M. T. Tsai, and Y. H. Huang (2013). "Mineralization and defluoridation of 2,2,3,3-tetrafluoro -1-propanol (TFP) by UV oxidation in a novel three-phase fluidized bed reactor (3P-FBR)," *Water Res*, 30.

Corresponding Author

Prof. Neha Baghele*

Assistant Professor, JSPM"s Imperial College of Engineering and Research, Wagholi, Pune

E-Mail – neha.baghele19@gmail.com