J. Appl. Environ. Biol. Sci., 5(8S)13-18, 2015

ISSN: 2090-4274
Journal of Applied Environmental and Biological Sciences
www.textroad.com

Mathematical Simulation for Petroleum Contamination Elimination of See Water by Moving Bed Reactor (MBBR)

Azin Rasapour*, Morteza Kashefi Asl

Chemical Engineering Department, Technical and Engineering Faculty, Islamic Azad University, Tehran North Branch, Tehran, Iran

Received: March 8, 2015
Accepted: May 10, 2015

ABSTRACT

MBBR systems used for municipal and industrial water treatment plants and So far were used for paper mill wastewater treatment, poultry, cheese factories, slaughterhouses, phenolic wastewater, dairy industry, urban waste water. The advantage of this reactor is that the Reactor volume is low compared to other wastewater treatment systems and do not require a backflow. All the benefits of using MBBR reactor is about most effective acne's area that cause of increasing biofilm in the reactor with small scale. In this paper, we simulate the mass transfer phenomena for oil pollution removing from water in a reactor with specific dimensions. Initially, the mass transfer equations are derived from a common source and equations numerically are solved with Matlab software. The results are compared with experimental results in this field and error is calculated.

KEYWORDS: oil pollution, sewage treatment, Fluidized bed reactors, mass transfer, MBBR reactor

1. INTRODUCTION

In industrial process water is used as irrigating, Coolants, solvents and etc. and through the use of water in industry often foreign substances in solution or suspension form, enters the water W and water quality is changed. If the concentration of this materials is greater than the standard value it is necessary that the wastewater produced to be treated. Sewer of different industries about the kind of contaminant, amount and toxicity are different that is due to the manufacturing process of the product. Risks associated with the oil and petrochemical wastewater have more importance and greater risk [2]. Due process and the need for high amount of water for cooling devices in the Oil and Petrochemical Industries basically, these industries are on the beach, Lakes and large rivers. Due to the country's vast oil resources they have complex of several petrochemical and related industries. One of the most important issues in these industries is waste production. So that their discharge regardless of environmental standards they will have following the devastating environmental effects. Effluents containing hydrocarbons are a lot of different families which, if not treated so environment and ecosystems will be threatened. Of physical, chemical and biological treatment of the different types of wastewater used in recent years and has been studied. One of the methods of biological is using of fluid bed reactor MBBR which has unique properties including low volume, with a high mass transfer due to acne, etc. The main objective of biological treatment and the use of these reactors are development and use of microorganisms to convert organic materials into other products, and reduction of nutrients and pollutants. The methods used can be aerobic or anaerobic [1, 3]. The biological fluidized bed reactors are usually aerobic and the ambient air is used by microorganisms. Bacteria in many aquatic and terrestrial environment of growth and activity in most cases, combination and size, are varied. Bacteria are used for wastewater and polluted water treatment. Biological phenomenon that increase metabolize potential of special hydrocarbons in a microbial population is known as microbial adaptation or agreement.

There are basically three biological mechanisms of microbial adaptation [5]:

1- Establishment of compatible enzymes or essential components
2- Changes in the special genetic codes due to new effective formulation in metabolic pathways
3- Selective enrichment by particular micro- organisms that are genetically capable for biodegradation of toxic compounds

The third mechanism is one of the most important processes for biodegradation of the hydrocarbons.

In this study of mixed cultures of bacteria will be used to evaluate experimental and how this culture works in bio- film system with high volume. Remove petroleum hydrocarbons alone or in combination in a laboratory scale has often been studied. But this was a pilot -scale studies have been conducted within the bioreactor less. In this study, we tried to simulate moving bed reactor for sea water treatment. This system because of need less space and cost to run And the ability to withstand high loads of organic and organic and hydraulic load changes and temperature and no clogging or swelling sludge is better selection rather than the fixed bed reactor and activated sludge [4]. Fixed bed reactors are generally perpendicular with low cross section and because this type of design is to achieve the desired volume with occupancy low area.

In this study, a mathematical model is presented which using of that is a better understanding mass transfer processes in three phases solid, liquid and gas as possible.

Corresponding Author: Azin Rasapour, Chemical Engineering Department, Technical and Engineering Faculty, Islamic Azad University, Tehran North Branch, Tehran, Iran, E-mail: azinrasa@yahoo.com

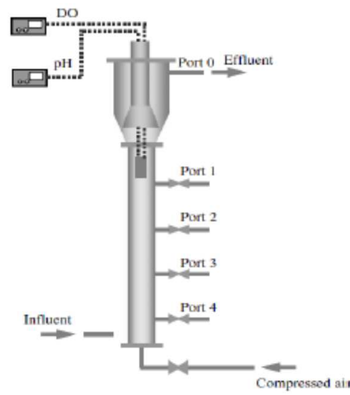
Mathematical model

This model is based on diffusion and convection effects in the flow and penetration into the biofilm and substrate concentration profile within the reactor is shown and explained.

Several simplifying assumptions used in the model that these assumptions are as follows [4]:

1- Biofilm layer was considered as constant
2- The adsorbent substrate radial concentration gradient in the three-phase was skipped
3- Carrier has a spherical shape and they have uniform biofilm size and thickness
4- substrate is transferred from liquid phase to biofilm by diffusion mechanisms

The following figure represents an MBBR reactor:



Biological elimination substrate, comprising the steps of mass transfer of oxygen from the gas bulk to surface of the bubble, mass transfer of oxygen from the surface of the bubble s to the liquid phase bulk, mass transfer of dissolved oxygen from liquid bulk to surface of the biofilm, diffusion and reaction of all materials within the biofilm according to Fick's law and monod synthetic [1,6] .

According to Fick's law and monod synthetic the balance of oxygen and other substrates within the biofilm solid phase are as follow equations as:

$$\frac{\partial Cis}{\partial t} = \left(\frac{D}{r^2}\right)\frac{\partial}{\partial r}\left(r^2\frac{\partial Cis}{\partial r}\right) - r_i$$

Equation.1

$$Cis(r,0) = Cis(0) \qquad at\ \ t = 0$$

Equation.2

$$Cis = Ci \qquad at\ \ r = r_p + \delta$$

Equation.3

$$\frac{\partial C}{\partial r} = 0 \qquad at\ r = r_p$$

Equation.4

In the above equation D is oxygen and other substrate diffusion coefficient into the biofilm, $r_p$radius acne, δ biofilm thickness and r_i is the rate of substrate consumption into the biofilm.

In the gas phase mass transfer equations and initial and boundary conditions are as follows:

$$\varepsilon_g\frac{\partial C_g}{\partial t} = -U_g\frac{\partial C_g}{\partial z} - K_l a(\frac{C_g}{M} - C_l)$$

Equation.5

Initial and boundary conditions for this equation as follows:

$$C_g = C_{gi} \qquad at \quad z = 0$$

Equation.6

$$C_g = C_{g0} \qquad at \quad t = 0$$

Equation.7

In the liquid phase mass transfer equations and initial and boundary conditions are as follows:

$$\varepsilon_l\frac{\partial C_l}{\partial t} = \frac{\partial}{\partial z}\left(E_{zl}\varepsilon_l\frac{\partial C_l}{\partial z}\right) - U_l(\frac{\partial C_l}{\partial z}) - \frac{D\ A_s\,\varepsilon_s}{L}(C_l - Cis)$$

Equation.8

Initial and boundary conditions for this equation as follows:

$$C_l - \left(\frac{E_{zl}\varepsilon_l}{U}\frac{\partial C_l}{\partial z}\right) = C_{li} \qquad at \quad z = 0$$

Equation.9

$$C_l = C_{l0} \qquad at \quad t = 0$$

Equation.10

$$\frac{\partial C_l}{\partial z} = 0 \qquad at\ z = H$$

Equation.11

In the above equations the C_{li} و $C_{gi}$are gas and liquid input,z axial location,E_{zl} axial diffusion coefficient of the liquid phase ,K_l mass transfer coefficient between gas and liquid phase ,a is average Interface of gas bubbles on the reactor volume and ε_l,ε_s,ε_g are the reactor volume occupied by liquid , solid and gas phases[2]. M is Henry constant, as is special surface carrier, Dcis diameter of column, Ul and Ug are the average velocity of liquid and gas phases and L is the thickness of constant liquid layer.

In the liquid phase mass transfer equations for oxygen and DO are as follows:

$$\varepsilon_l\frac{\partial C_l}{\partial t} = \frac{\partial}{\partial z}\left(E_{zl}\varepsilon_l\frac{\partial C_l}{\partial z}\right) - U_l\left(\frac{\partial C_l}{\partial z}\right) - \frac{D\ A_s\,\varepsilon_s}{L}(C_l - Cis) + K_l a\left(\frac{C_g}{M} - C_l\right)$$

Equation.12

Relation between different speeds and axial diffusion coefficient of the liquid phase and reactor column diameter and the diameter of acne are as follows:

$$\frac{d_p U_l}{E_l} = 20.19\left(\frac{d_p}{D_c}\right)^{1.66}\left(\frac{U_l}{U_l + U_g}\right)^{1.03}$$

Equation.13

Monod Synthetic are as follows:

Rate of changes in the biomass is obtained from following differential equation:

$$r_x = \frac{d_x}{d_t} = \mu\,.\,x$$

Equation.14

rx: Biomass growth rate in milligrams per liter per hour:

μ: Specific growth rate constant per unit time

X: Concentration of bio mass at any time

Equation.14 shows the growth rate of biomass relative to its concentration is first degree and it can be written as follows:

$$r_x = \frac{1}{x}\frac{d_x}{d_t} = \frac{r_x}{x}$$

Equation.15

And

$$\mu = \mu_{max}\frac{s}{Ks + s}$$

Equation.16

μ max : The maximum specific growth rate constant per unit of time

S: Organic matter concentration at any time

Ks: Half- saturation constant

Given that the rate of conversion of substrate to the biological mass is equal to:

$$Y_{obs} = \frac{x - x_o}{s_o - s}$$

Equation.17

Yobs: Organic matter is converted into biological mass

Equation 17 can be written as:

$$\mu = \frac{1}{x}\frac{d_x}{d_t} = \mu_{max}.\frac{s_o + \frac{x_o - x}{Y_{obs}}}{s_o + \frac{x_o - x}{Y_{obs}} + k_s}$$

Equation.18

According to equation.18 it is expected that with increasing x that occurs over time to reach μmax.

In fact , Yobs ratio is a relationship between Yobs and Real efficiency coefficient Y_{sx} that is defined as below :

$$\frac{1}{Y_{obs}} = \frac{1}{Y_{sx}} + \frac{m_s}{\mu}$$

Equation.19

Where Ysx and ms (inductive energy factor) are fixed for a particular reactor. In this case Yobs can be fixed. If the Yobs be constant and we substitute equations we can obtain following equation:

$$\mu_{\max}.t = \left(1 + \frac{K_s}{S_o + {X_o}/{Y_{obs}}}\right) ln\left(\frac{x}{x_o}\right) - \left[\frac{k_s}{s_o + {x_o}/{Y_{obs}}}\right] \ln\left[1 - \frac{x_o}{S_o Y_{obs}}\left(\frac{X}{X_o} - 1\right)\right]$$

Equation.20

These equations are general and must be solved numerically for the desired reactor. After solving the equations numerically the results must be compared with experimental results and error must be calculated and optimized.

Numerical calculations

All differential equations listed in the mathematical model are partial derivative equations of parabolic type in two variables and must simultaneously solved. In all of them function variable is concentration and other variables are time and a place. The spatial dimension of the first differential equation which investigate the solid phase concentration of the biofilm on the surface of the carrier and acne is radius that resulting solution of this equation is concentration profile along the thickness of the biofilm which mechanism of the mass transfer is diffusion and reaction synthetic is Monod. In other equations that shows oxygen and other substrate concentration in the gas and liquid phases, spatial dimension is reactor length that resulting solution of these equations are concentration profiles along the reactor for all of the substrates.

To solve equations must place of desired range has been meshed and then all the equations, must write ar discrete and finite difference form and after discretization of parabolic equations with respect to the explicit or implicit methods we can solve equations. The explicit method is straightforward and simple but it will be unstable sometimes. Implicit methods has greater complexity, but always within the context of sustainable. In these research for solution of the equations we use implicit method and after creating the matrix of known and unknown coefficients, Thomas method is used to transform and simplify the resulting matrix. For discreting of first order derivatives equations we use backward and forward forms and for second order derivatives equations we use central form.

Code corresponding equations in MATLAB program was written to a M file and all programs are placed in a repetitive loop until convergence become minimum. To solve equations in this study, the number of nodes in the reactor within a length about 25 and within acne radius is about 10.

Boundary conditions for these equations are first and second kind of boundary conditions and should be discrete as finite difference forms.

RESULTS

The following figures are comparison between the experimental results and the results of the model [7].

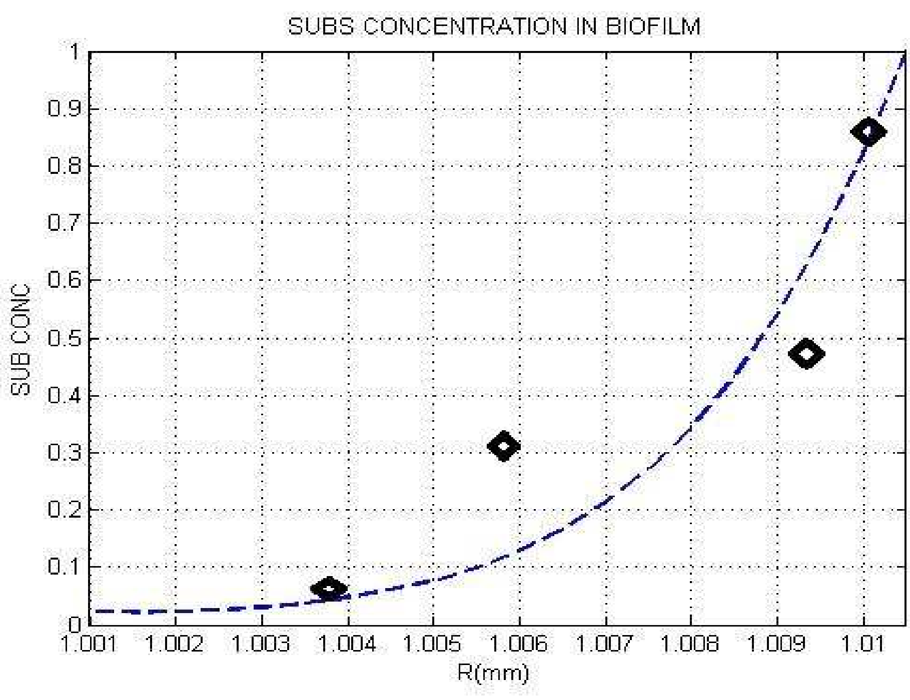


Figure .1

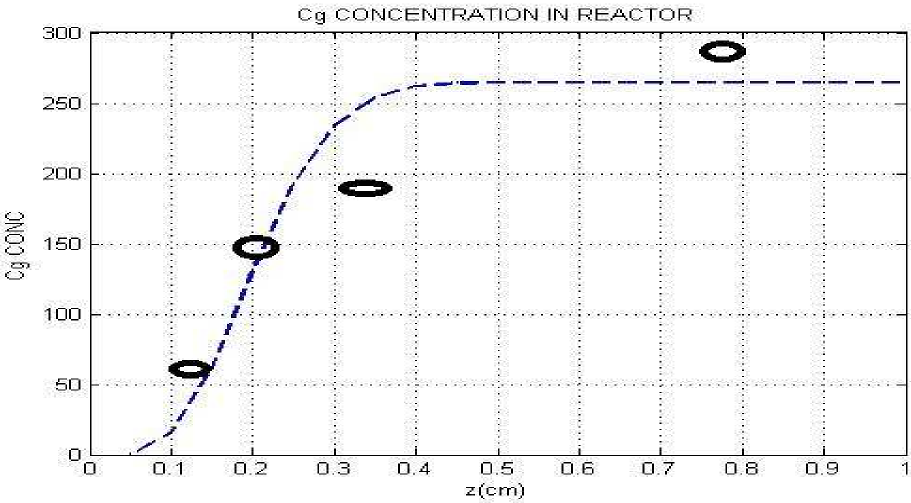


Figure.2

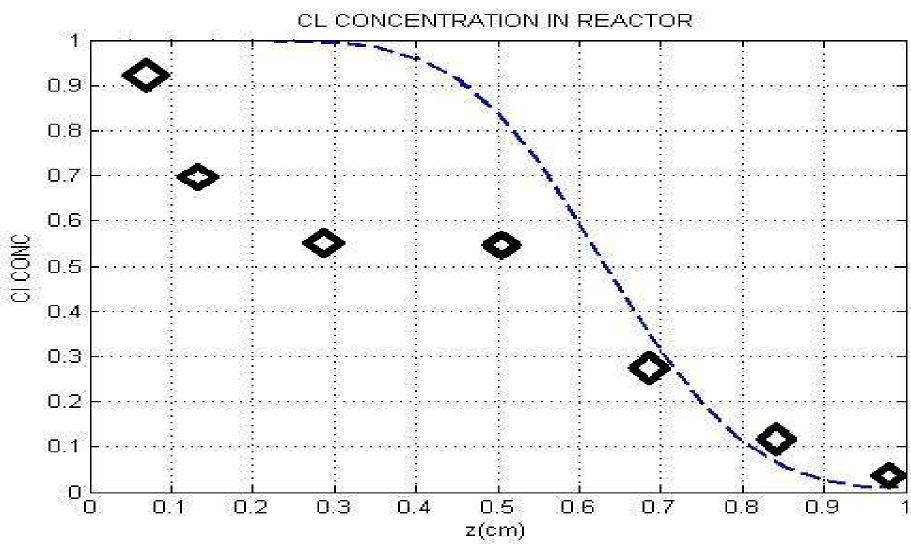


Figure.3

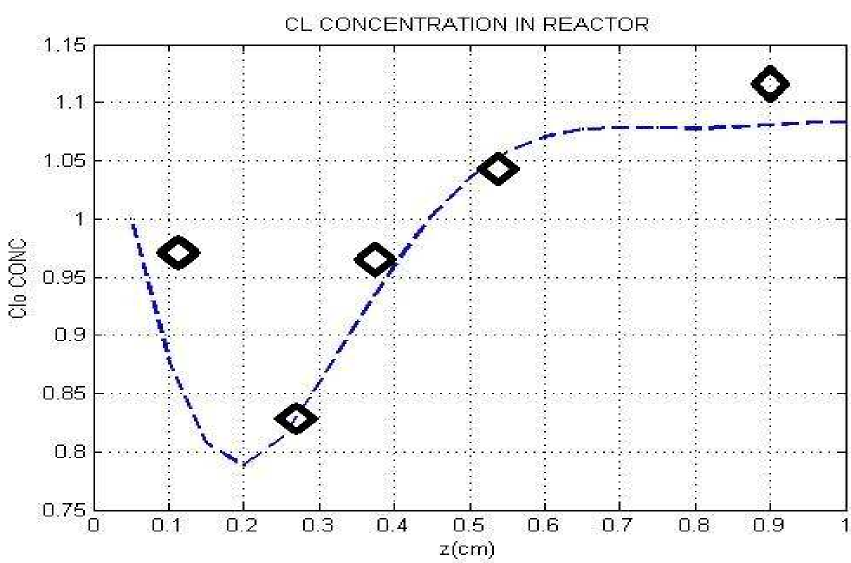


Figure.4

CONCLUSION

This investigation demonstrated that MBBR filled with the suspended carrier was an effective and feasible process for removal petroleum hydrocarbons from see water. The modification of bio carrier with different material produced positive outcomes in the wastewater treatment Efficiency.

REFERENCES

[1] Dentel, S.K and Sen, P, “Simultaneous nitrification–denitrification in a fluidized bed reactor”. Water Sci. Technol, 38 (1), 247–254 1998.

[2] A. Ulson,S and H. Brand and G. Souza , Selene ,M.A, “Modeling of liquid pollutant biodegradation process in a fluidized bed reactor with biofilm” Separation and Purification Technology.60,162-173, 2008.

[3] H. Shi, Q. Wen and Z. Chen, “T-RFLP detection of nitrifying bacteria in a fluidized bed reactor of achieving simultaneous nitrification–denitrification” CHemosphere.71,1683-1692, 2008.

[4] Yen-Hui Lin ,"Kinetics of nitrogen and carbon removal in a moving-fixed bed biofilm reactor ", Applied Mathematical Modelling, 2360–2377,2008.

[5] A. Lohi L. Wan, M. Alvarez-Cuenca, S.R. Upreti, "Development a three-phase fluidized bed reactor with enhanced oxygen transfer", Chemical Engineering and Processing ,49, 2–8,2010.

[6] F.Larachi, M.C.Iliuta, I.Iliuta,and S.C.Bildea, "Analysis of trickle bed and packed bubble column bioreactors for combined carbon oxidation and nitrification", Brazilian Journal of Chemical Engineering,2002

[7] Zhiyong Donga,., Mang Lub, Wenhui Huangc, Xiaochun Xud, " Treatment of oilfield wastewater in moving bed biofilm reactors using a novel suspended ceramic biocarrier " Journal of Hazardous Materials 196 (2011) 123– 130