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Adsorption Process for Acrylic Acid Removal from Wastewater

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Abstract

The objectives of this study were to develop the mathematical model of the adsorption process of the acrylic acid by using the activated carbon and also to validate the simulation of the adsorption process by using the experimental data. Simulation of the adsorption process is necessary to understand the acrylic acid removal using adsorption process. Acrylic acid is removed from the waste water because it can cause serious damage to the environment due to its high toxicity for the aquatic organisms. As a conclusion, the objective is expected to achieve. The new mathematical model of the adsorption process of the acrylic acid by using the activated carbon can be created. The validation of the simulation is carried out to compare the simulation data with the experiment data.

Keywords: *adsorption, mathematical modeling, activation carbon*

Introduction

Adsorption is typically used in wastewater treatment to remove toxic or recalcitrant organic pollutants and to a lesser extent, inorganic contaminants, from the wastewater. Adsorption finds applications in tertiary wastewater treatment as a polishing step before final discharge. Adsorption is commonly used in the treatment of industrial wastewaters containing organic compounds not easily biodegraded during secondary (biological) treatment or toxic. In the adsorption process, acrylic acid is removed from waste water by using the activation carbon. The activation carbon has ability to remove the contaminants from the water. Acrylic acid is removed from waste water because it contain high toxicity that can harmful the aquatic organism. The adsorption process is used in the waste water treatment because it has low cost operation and has high efficiency.

Acrylic acid is also known as propenoic acid which has a colorless transparent liquid which a pungent smell. The boiling point of acrylic acid is 141.0^0C and the melting point is 13.5^0C. Its density is 1.045 g/ml. Acrylic acid is produced from propene which is a byproduct of ethylene and gasoline production. This corrosive chemical is miscible in water, alcohol, and esters and polymerizes readily in the presence of oxygen forming acrylic resins. Acrylic acid is a strong corrosive agent to many metals, such as unalloyed steel, copper and brass. Acrylic acid undergoes reactions characteristics of both unsaturated acids and aliphatic carbolic acids or esters. Acrylic acids also can be polymerizing very easily. Acrylic acid is widely used in several industries such as painting, chemical fibers, adhesives, paper, oil additives and also detergent. When the acrylic acid released in effluents serious damaged to the environment can be cause because it has high toxicity for aquatic organisms.

Adsorption is a process where a solid is used for removing a soluble substance from the water. In this process active carbon is the solid [1]. Adsorption is a process that occurs when a gas or liquid solute accumulates on the surface of a solid which is called as adsorbent or the material doing adsorbing, forming a molecular or atomic film which is called as the adsorbate or material that being adsorbed [1]. It is different from absorption, in which a substance diffuses into a liquid or gases.

Activated carbon is also called activated charcoal or activated coal is carbon produced from the carbonaceous source materials such as nutshells, peat, wood, coal and petroleum pitch. For all three variations of the name, "activated" is sometimes substituted by "active" [2]. Activated carbon does not bind well to certain chemicals such as alcohols, strong acids and bases, and most inorganic like sodium, lead and iron. However, the activated carbon can adsorb the iodine very well compare to the others. Activated carbon is produced by a process consisting of pyrolysis of raw material followed by activation with oxidizing gases [3].

Activated carbon is an excellent adsorbent because it has a strong affinity for binding organic substances, even at low concentration. Activated carbon also has a vast network of pores of varying size to accept both large and small contaminants molecules and these pores also give activated carbon has a very large surface area. The larger percentage of the total surface area is believed to be of the planar surface type with the attached functional groups [4]. The majority of the adsorption on the surfaces considered because of the relative weak physical or Van der Waals forces [5]. On the other hand, the sides of these planar surfaces are attached with many functional groups such as organic carboxyl, phenol and also carbonyl group [6] and inorganic oxygen complexes [4].

Methodology

The mathematical modeling is created based on the mass balance of the fixed bed adsorption. A mathematical model for the fixed bed column is proposed by incorporation for an important parameter, external mass transfer, resistance, internal mass transfer resistance and non-linear multi component isotherm. The proposed model can be extensively used for understanding the dynamics of fixed bed adsorption column. [7].

The net rate of the accumulation:

$$-D_L \frac{d^2C_b}{dz^2} + V\frac{dC_b}{dz} + C_b\frac{dV}{dz} + \frac{dC_b}{dt} + \rho_p\left(\frac{1-\varepsilon}{\varepsilon}\right)\frac{dq_p}{dt} = 0 \qquad (1)$$

Total mass balance:

$$\rho_1 \frac{dV}{dz} = -(1-\varepsilon)\rho_s \frac{dq_p}{dt} \qquad (2)$$

The inter phase mass transfer rate:

$$\rho_s \frac{dq_p}{dt} = \frac{3k_f}{a_p} + (C_b - C_s) \qquad (3)$$

The adsorption isotherm is nonlinear:

$$q = \frac{q_m bc}{1+bc} \qquad (4)$$

Simulation using Matlab Software

Based on the mathematical model of the fixed bed adsorption, the simulation by using Mat lab is created. The equation is modified by using different parameters and variables such as the initial concentration of the absorbent, the height of bed column, the detention time used adsorb the adsorbate and the weight of adsorbent removal. The simulation is run by using the ordinary differential equation (ODE).

Results and Discussions

Effect on concentration of acrylic acid removal versus time

Figure 1 shows the effect of percentage removal concentration of acrylic acid removal versus time contact. From the graph, the concentration percentage acrylic acid removal is increase as the time increase. According to Senthilkumaar, et. al. [8], said that the concentration of the percentage removal is increasing with the increasing of the time contact. During the adsorption of the acrylic acid, the initial of acrylic acid molecules reach to the boundary layer. During adsorption of acrylic acid, the initial of the acrylic acid molecules reach the boundary layer and then acrylic acid have to diffuse into the adsorbent surface. Finally, acrylic acid has to diffuse into the porous structure of the adsorbent. Hence, this phenomenon will take a relatively longer contact time.

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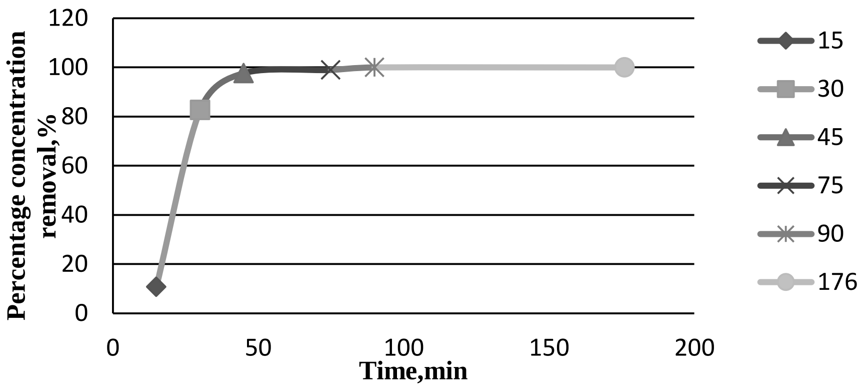

Figure 1. Percentage of acrylic acid removal versus time

Table 1. Percentage of adsorption removal under time contact

Time, min	Final Concentration, ppm	Percentage of acrylic acid removal, %
15	5.86	10.67
30	1.142	82.60
45	0.151	97.70
75	0.0634	99.00
90	0.0000	100.00
176	0.0000	100.00

Effect on concentration of acrylic acid removal versus initial concentration

Figure 2 shows the effect of percentage removal concentration of acrylic acid removal versus initial concentration. From the graph, the initial concentration is perpendicular to the concentration of acrylic acid removal. As the initial concentration is increase, the concentration of acrylic acid removal is also increase. This is because of the higher the acrylic acid, the stronger the driving forces of the concentration gradient, thus the higher the adsorption capacity [9].

As expected, the breakpoint time for a higher dye concentration was earlier than that for a lower influent dye concentration as the binding sites became more quickly saturated in the system at higher dye concentrations. Higher inlet dye concentrations caused a faster breakthrough as expected [10].

Figure 2 shows that the first initial concentration of acrylic acid which is 6 ppm can remove 72.6 percentage of the acrylic acid removal. The initial concentration of acrylic acid is rapidly increase because of the relatively slower transport due to a decrease in diffusion coefficient and also decreased mass transfer coefficient at low acrylic acid concentration [11].

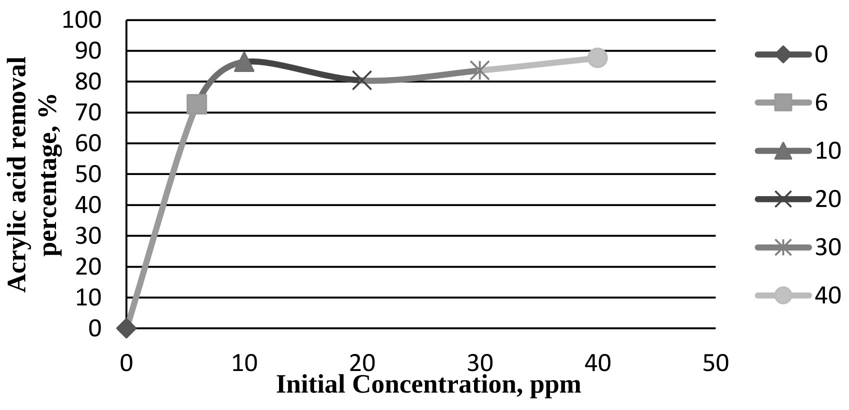

Figure 2. Percentage of acrylic acid removal versus initial concentration

Table 2. Percentage of adsorption removal under initial concentration

Initial Concentration, ppm	Final Concentration, ppm	Percentage of acrylic acid removal, %
6	5,860	72,60
10	1,644	86,40
20	1,364	80,35
30	3,930	83,63
40	4,910	87,70

Conclusion

As a conclusion from the research, the findings and the mathematical modeling that have been done and the results obtain will help the researcher to improve the kinetics and equilibrium studies on the acrylic acid removal from the wastewater by using granular activation carbon. The data showed that the prepared activated carbon has considerable potential for the removal of acrylic acid from wastewater treatment. For the validation of the simulation is carried out to compare the simulation data with the experiment data. This research is expected to improve the understanding of adsorption process of acrylic acid using activated carbon.

Nomenclature

a_p	:	radius of the adsorbent pellets	[m]
C_b	:	bulk phase dye concentration	[mg/ml]
C_s	:	liquid phase concentration in equilibrium with qs on the surface	[mg/ml]
D_L	:	axial dispersion coefficient	[m^2/s]
k_f	:	external film mass transfer coefficient	[m/s]
q	:	average adsorbed phase dye concentration	[mg/g]
q_m	:	Langmuir isotherm parameter	[mg/g]
t	:	time	[sec]
V	:	superficial velocity	[m/s]
z	:	axial coordinate	[m]
ε	:	bed porosity	

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