Management of Butachlor Bearing Water by Waste Tire Rubber Granules

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Abstract

Scarcity of drinking water is one of the major problems in Bangladesh. Use of waste tyre rubber granules as a filter media has been identified to treat butachlor-bearing water. Waste tyre rubber granules have been used in a fixed bed column reactor. The experiment has been conducted with 2 mg/l of initial butachlor concentrations for bed depth of 25 cm. It has been found that 1 gm of waste tyre rubber granules can purify 0.021 liter of distilled water and 0.018 liter of tap water having 2 mg/l of butachlor. Experimental data has been found to have a better correlation with BET isotherm based theoretical breakthrough curves. Service time obtained from BDST approach and experimental breakthrough curves are found to very close. Efficiency of the system has been found 80% and 73% based on contact approach and adsorbent usage approach, respectively.

INTRODUCTION

Every year about 15 million people are suffering from water borne diseases in Bangladesh. Due to scarcity of pure drinking water, people consume water from nearby polluted sources. Locally available waste materials can be used as a filter media for the purification of polluted water. Dumping problem of waste tire rubber is well known in developed as well as developing countries. The projected use of tire in 2001 is 4,09,13,000 in India although it was 2,78,47,000 in five years ago. So it can be assumed that tire dumping will be an environmental threat in near future. Many potential uses of waste tyre rubber as a sorbent have been investigated for removal of heavy metals, hydrogen sulfide, ammonia and volatile organic compounds (Barbash *et al*, 1996; Cloutier *et al*, 1985; CRRI, 1998; Croll *et al*, 1992). In this paper, an attempt has been undertaken to find out the suitability of waste tyre rubber granules as an adsorbent in a fixed bed column to treat butachlor bearing water samples.

It has been reported that millions of Americans of 374 communities of 12 states are exposed to toxic herbicides as toxic chemicals are frequently found in their tap water. In a study of 178 water systems in the Midwest, presence of butachlor and atrazine were found in 96% of those water systems (EMS, 1997). In India, surface water of Ganges at different stretches, some lakes and canals of West Bengal and Raipur have been reported to contaminate with insecticides and herbicides (SenGupta *et al*, 1985; Thakkar *et al*, 1986).

Pesticide data were collected between the year 1985 and 1996 in the NAWQA program within five study units of Mid-Atlantic region (Jones *et al*, 1992). It was found that out of 543

samples, 292 samples (54%) contained detectable levels of atrazine, desethylatrazine, metolachlor, prometon, butachlor or simazine. Atrazine and desethylatarzine were the most frequently detected pesticide compounds comprised in 39% and 43% of samples respectively. 275 representative samples contained detectable concentrations of atrazine or desethylatrazine or both (Jones *et al*, 1992).

METHODS

Experimental column tests were conducted with initial concentration of 2 mg/l of herbicide for the bed depth of 25 cm. Flow rate was kept at 8 ml/min. Waste Tyre Rubber Granules of size 0.15 - 0.30 mm was sandwiched between two layers of glass wool. Upward flow was maintained in order to avoid clogging of bed.

RESULT AND DISCUSSION

Breakthrough Curves
In this study, breakthrough curves have been developed for a single solute system with waste tyre rubber granules. Initial concentration of 2 mg/l was maintained throughout the experiment. A bed depth of 25 cm was used. It has been observed that 1 gm of rubber granules can treat 0.021 liter and 0.018 liter of distilled water and tap water samples respectively spiked with 2 mg/l of herbicides. Breakthrough curves for distilled water and tap water are shown in Figure-1 and Figure-2 respectively. Tap water system has an earlier breakthrough with respect to distilled water system, although both curves closely follow each other. The presence of cations (Ca^{++} and Mg^{+2}) and alkalinity in tap water are responsible for earlier breakthrough. The breakthrough point is positively correlated with bed depth and negatively correlated with sorbent size, flow rate and influent adsorbate concentration (Rowley *et al*, 1984).

Design of Fixed Bed Column
When wastewater is introduced at the top of a clean bed of activated carbon, the solute removal initially occurs in a rather narrow band at the top of column called the adsorption zone. As operation goes on, the upper layer of carbon become saturated with solute and the adsorption zone progresses downward through the bed and solute concentration in the effluent begins to drop.

Although the rational design of the adsorption column based on batch adsorption data and mass transfer coefficient is not possible, however it is possible to obtain empirical relationships for the design. One of the most widely used methods is the Bed-Depth Service Time (BDST), which is the simplified form of the Bohart-Adams Model based on surface reaction theory (Rowley *et al*, 1984). The advantage of this design approach is that the necessary data can be collected by batch studies, which is less time-consuming and less expensive than other methods. But the difficulty of evaluation of mass-transfer coefficient, k_{ff} is the main limitation of this method. The slope of the BDST line represents the time required for adsorption zone to travel a unit length of the rubber granules column. The critical depth indicates minimum rubber granule depth needed to reach a satisfactory effluent at time zero under experimental conditions. It has been found that the experimental breakthrough curve follows the theoretical breakthrough curve.
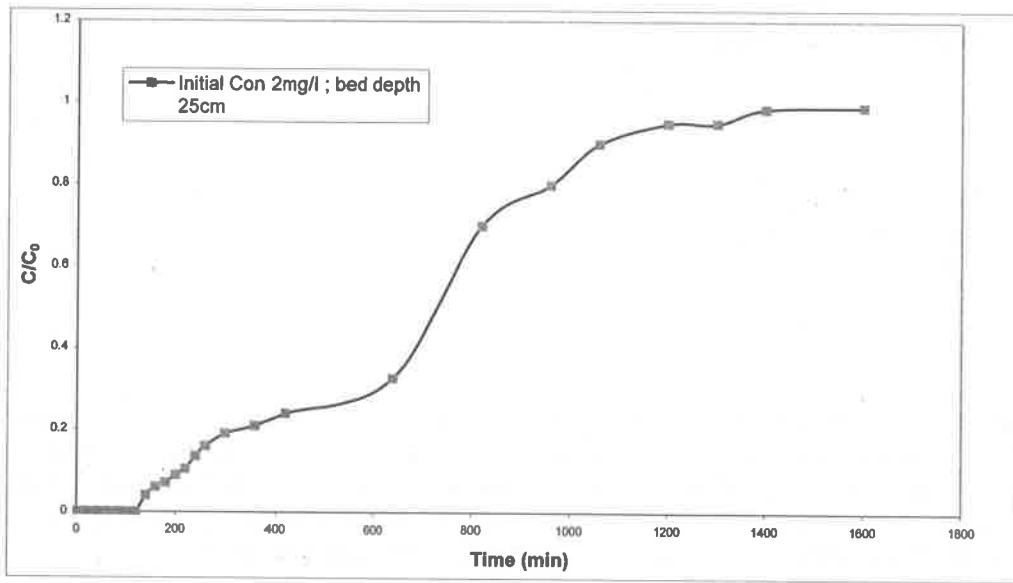
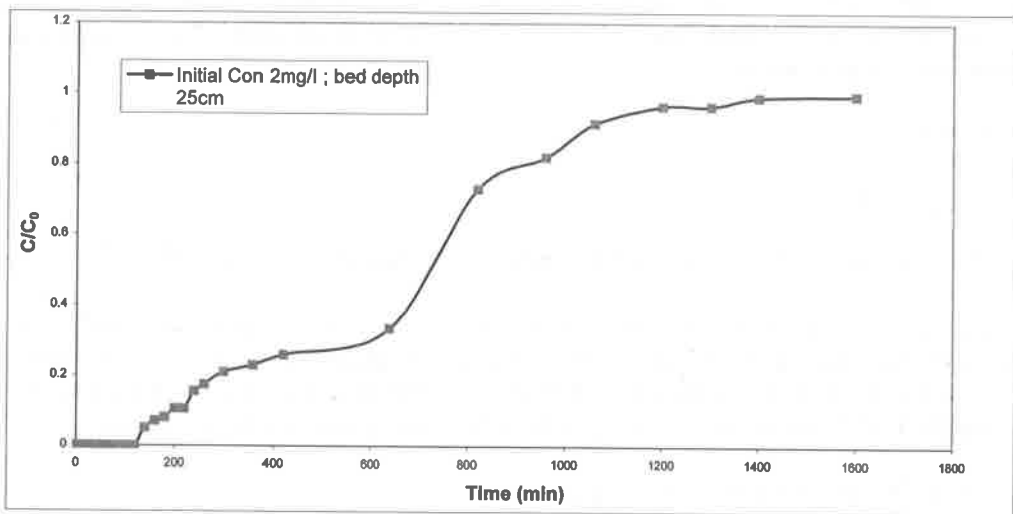**Fig. 1. Breakthrough curve for Butachlor-Rubber Granules System mixed with distilled water**

Fig.2. Breakthrough curve for Butachlor-Rubber Granules System mixed with tap water

The design of fixed bed adsorbent involves evaluation of the breakthrough curve and the occurrence of break point. A single organic sorbate in solution yields a sharp breakthrough curve such that the bed is almost exhausted when breakthrough occurs. Bohart and Adams (Croll *et al*, 1992) have developed a relationship, which can be used to predict the performance of continuous carbons beds.

By simplifying the relationship:

$$In(\frac{C_0}{C_B}-1) = In(e^{KN_0.X/V}-1)-KC_0t$$

$$t = \frac{N_0}{C_0v}(x-\frac{v}{(KN_0)}In(\frac{C_0}{C_B}-1))$$

$$b = -\frac{1}{KC_0}In(\frac{C_0}{C_B}-1)$$

Where t is service time (min), v is linear flow rate (cm^3 min^{-1}), x is depth of the bed (cm), K is rate constant (cm^3 mg^{-1} hr^{-1}), N$_0$ is sorptive constant, (mg cm^{-3}), C$_0$ is influent concentration (mg cm^{-3}), and C$_B$ is permissible effluent concentration (mg cm^{-3}). The bed depth which is theoretically just sufficient to prevent penetration of concentration in excess of C$_B$ at zero time, is defined as critical bed depth and is determined from equation when t =0.

The sorptive capacity N$_0$ can be determined from the slope of a linear plot of t versus X and the rate constant K is the intercept of this plot. Hutchins 1973, presented a modification of the Bohart-Adams equation, which requires only three fixed bed tests to collect the necessary data. This is called the Bed Depth Service Time (BDST) method. The Bohart-Adams equation can be expressed as

$$t = aX + b$$

$$X_0 = \frac{v}{KN_0}In(\frac{C_o}{C_B}-1).$$

Where the slope, a = N$_0$/(C$_0$v) and the intercept, b = - (1/KC$_0$)(In ((C$_o$/C$_B$) -1).

If a value of "a" is determined from a flow rate (v), values for other flow rates can be computed by multiplying the original slope by the ratio of the original and new flow rates, the value of intercept b is insignificant with respect to variable flow rates (Hutchins, 1973). Applying the BDST approach, efficiency of butachlor adsorption can be calculated.

Bulk density of sorbent = 0.283 g cm^{-3}
Sorbent particle size =0.15-0.3 mm

The design parameters according to BDST approach were calculated as follows:
Flow rate, u =8.0 ml min^{-1}
Sorption velocity, v = 1/slope = 1/0.4668 = 2.14 cm hr^{-1}
Rubber granules used, Aug = 4.30 g hr^{-1}
Rubber granules sorption loading = 0.10 mg g^{-1}
Sorption capacity, N$_0$ = C$_0$va = (2/1000) x 0.565 x 0.4668 x 60 = 0.03165 mg cm^{-3}
K= (1/(2 x 2.32)) * In (2/0.2 - 1) x 1000 = 473.6 cm^3 mg^{-1} hr^{-1}

For depth h = 25 cm

X$_0$ = ((0.565 x 60)/(473.6 x 0.03165)) *In (9) = 4.97 cm
Service-time, t = ((0.03165)/(0.002*0.565))(25 - (v/KN$_0$)In (9))= 9.35 hr

Efficiency based on Butachlor adsorbed:

$$\text{Efficiency} = v \, t \, (C_0 - C_B) / (\text{total capacity})$$
$$= ((4/1000) \times 9.35 \times 60 \times 1.8)/ (0.78 \times 9 \times 25 \times 0.03165) = 72.7\%$$
$$\text{Efficiency based on } X_0 = (25 - 4.97)/25 = 80.1\%$$

For economic optimization of the sorption process of Butachlor on rubber granules, pressure drop studies should be incorporated. According to Cloutier *et al.* 1985, reliable pressure drop data could not be obtained with laboratory setup and can be determined from pilot-plant scale columns. Efficiency of the system is 80% and 73% based on contact approach and adsorbent usage approach respectively. So, by using BDST design approach, service time can be predict accurately and can be adopted.

Regeneration of Spent Sorbent in Fixed Bed

In this study downward regeneration was carried out. The rubber granules were first fed with Butachlor–distilled water for about 7 hr for attaining breakthrough at a flow rate of 8 ml min^{-1} and with an initial concentration of 2 mg/l. When the adsorbent being fully exhausted, column regeneration studies were subsequently carried out using 15% acetone solution. The downward regeneration was carried out in this study at a flow rate of 12 ml min^{-1}. Desorption of herbicides (butachlor) by the dilute solvent solution (15% acetone) is due to the solubility mechanism that make the bond between the herbicide molecules and rubber granules weak.

CONCLUSIONS

It has been found that the breakthrough times are 180 min for bed depth of 25 cm. Presence of calcium and magnesium ions has adverse effect on the breakthrough points. The experimental data and the theoretical values calculated based on BET equation was coinciding. The service time obtained from the BDST approach is approximately similar to the experimental breakthrough curve. The efficiency of the system is 80% and 73% based on contact approach and adsorbent usage approach respectively. Therefore the BDST design approach can predict the service time accurately and can be adopted. The initial concentration, presence of other herbicides and flow rate of influent has also effect on the breakthrough point. It has been found that the breakthrough for initial concentration of 1 mg/l is 1.98 times than that of for 2 mg/l considering that other conditions are fixed. 15% acetone solution has been used for regeneration of fixed bed column.

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