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Laboratory Worksheet P4 : **Adsorption Breakthrough Curve**. by *WS LAM*

Objective : To determine the fractional capacity and the depth of adsorption zone of an activated carbon column.

Introduction

Three types of activated carbon adsorption processes are in common use: fixed bed downflow, fixed bed upflow and fluidized beds. Although all three can be designed in the same fashion, they do have different operating characteristics. Downflow processes are the most susceptible to plugging and, consequently, should be used only for waters of low turbidity. Upflow systems tend to plug less because of the direction of flow. Plugging is not a problem with fluidized beds, but problems associated with abrasion and particle breakup can be significant.

Processes are most easily designed through the use of breakthrough curves obtained in pilot plant studies. These curves relate the effluent organic concentration to the volume of water treated and can be used to develop column characteristics. In the downflow situation described by Fig. 1, the saturated zone is shown to move through the bed preceded by a zone of active adsorption with depth δ. It is assumed that all the adsorption takes place in this latter zone and the region behind the active zone is completely saturated. When the front of the active zone reaches the bottom of the bed, breakthrough occurs and the effluent concentration begins to rise rapidly. In practice, the determination of breakthrough is somewhat arbitrary, and usually either the effluent requirement or 5% of influent concentration is used as a value. Exhaustion is usually defined as 95% influent or when there is no further increase of the effluent concentration.

A major part of breakthrough curve analysis is concerned with the determination of the fractional capacity f and the depth δ of the adsorption zone. This information can then be used to predict the effective column capacity. These parameters will change with changes in flow rate due to different conditions of dispersion, diffusion an channeling.

Define

$$P_s = \int_{V_b}^{V_x} (C_i - C_e)\, dV$$

$$P_{tc} = (V_x - V_b)\, C_i$$

$$f = \frac{P_s}{P_{tc}}$$

where P_s = quality of material adsorbed in the adsorption zone from breakthrough to exhaustion.

P_{tc} = total adsorption capacity of the carbon in the adsorption zone.

C_i = influent concentration.

C_e = effluent concentration.

V_b = effluent volume at breakthrough.

V_x = effluent volume at exhaustion.

and

$$\delta = \frac{L(V_x - V_b)}{V_b + f\,(V_x - V_b)}$$

where L = column length.

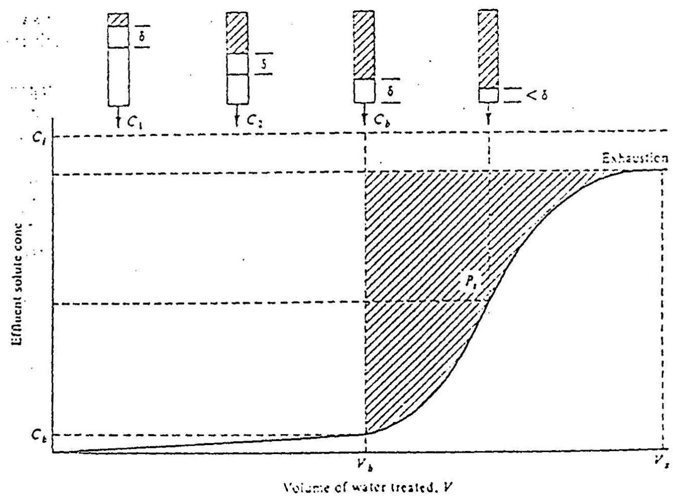

Fig. 1 Downflow Adsorption Breakthrough Curve.

Apparatus and Materials

- Spectrophotometer
- Volumetric flasks
- Activated Carbon
- Glass Column
- Methylene Blue Solution

Procedure

Standard Curve calibration

1. Prepare 1, 2, 5, 8, 10, 15 and 20 ppm of standard methylene blue solutions.
2. Measure the absorbances of the standards at 660 nm using a spectrophotometer.
3. Plot absorbances against standard methylene blue concentrations to obtain a calibration curve for unknown methylene blue concentration measurements.

Breakthrough Curve construction

1. Weigh a certain amount of activated carbon and pack it into the column. (10g for 10mm dia. column or 60g for 25mm dia. column.)

2. Fill the column with distilled water and flush the column until the effluent water becomes clear.

3. Let the distilled water flow until the water level drops to the top of the carbon bed and stop the flow. Measure the length and diameter of the carbon bed.

4. Fill the column with influent sample and prepare to collect effluent sample.

5. During the experiment, the effluent volume must be measured accurately.

6. Measure the absorbance of the influent sample.

7. Start and adjust the effluent flow to about 5 mL/min., take 5 mL of effluent and measure its absorbance at 660 nm.

8. At every bed volume of effluent, collect 5 mL of effluent and determine its absorbance at 660 nm until exhaustion.

Calculation

Determine P_s by using numerical integration or by area estimation and hence find f and δ.

Discussion

Total Sorptive Capacity to breakthrough is defined as

$$S_b = (\frac{x}{m})C_i \rho_p [(L-\delta)+f\delta]$$

where S_b = total Sorptive Capacity to Breakthrough, i.e. mass of sorbate adsorbed per unit of cross-sectional area (g/m^2).

$(\frac{x}{m})C_i$ = mass of sorbate absorbed per unit mass of carbon at equilibrium concentration C_i.

ρ_p = apparent packed density of the sorbent (g/m^3).

L = bed depth.

How can an engineer determine S_b by the carbon breakthrough curve and the carbon absorption isotherm ?

