



DISCUSSION

5.1 Some Considerations on the Selection of
Adsorbent and Adsorbates

The adsorption of impurities from aqueous solution in fluidizing column seems to be the complicated one by the heterogeneity of the solute system. In this research, certain qualitative operating criteria can be set forth on the basis of knowledge of the general behavior of adsorption systems. Both of single-solute and multisolute systems were studied. Adsorbates selected for this research were considered to be valuable for applying in industrial use or for the background in studying adsorption in condition that leads to approach actual condition found in industrial waste. Formaldehyde was selected for it is one of impurities in waste water from synthesis of pine gum. For sodium hydroxide and sodium carbonate, the selection was based on the ease in determination of their individual concentration in mixture. The method used for analysis the quantities of sodium hydroxide and sodium carbonate in mixture was Winkler's method (44). The adsorption of sodium hydroxide and sodium carbonate in single solute aqueous solution were also studied and compared to those in multisolute aqueous solution. Granular activated carbon was selected for the economic consideration which shown in Table 2.2. Granular activated carbon SGL type Pittsburg Activated Carbon & Co., Inc. was selected for using as adsorbent.

5.2 Equilibrium Adsorption

5.2.1 Equilibrium Adsorption of Formaldehyde

The equilibrium adsorption of formaldehyde at 30°C illustrated as graphical result in Fig A-1 shows the adsorption for 2 periods of time, 24 hours and 48 hours. It is observed that cumulative uptake of formaldehyde (m) for the adsorption of 48 hours and for 24 hours are approximately equal. The result showed that the contact time 24 hours is enough for reaching equilibrium. For adsorption of phenol (33), the equilibrium took place after 46 hours. The equilibrium adsorption of formaldehyde might be reached approximately 24 hours after beginning.

5.2.2 Equilibrium Adsorption of NaOH and Na₂CO₃ in Single-solute Aqueous Solution

For comparison, the result shown in Fig A-2 and Fig A-3 for isothermal equilibrium adsorption of NaOH and Na₂CO₃, the adsorption of NaOH is greater than of Na₂CO₃ and both are less than formaldehyde for the same concentration. This can be concluded that activated carbon is a poor adsorbent of inorganic electrolytes comparison to those of organic molecule. This phenomena had also pointed out in Pittsburg paper (3).

5.2.3 Equilibrium Adsorption of Mixture of Sodium Hydroxide and Sodium Carbonate

Isothermal adsorption of mixture of sodium hydroxide and

sodium carbonate is shown in Fig A-4 by plotting cumulative uptake of solute with equilibrium concentration. It is observed from Fig A-4 that adsorption of NaOH shows a higher carbon capacity comparable to the other one, Na_2CO_3 . This phenomena can be explained by the chemical nature of the surface. Generally, a pure carbon surface is considered to be nonpolar; but in actual practice, some carbon oxygen complexes are usually present which render the surface slightly polar. Coughlin (42) pointed out that acidic surface oxides of carbon are in particular formed under the most usual conditions of treatment and manufacture of activated carbon. For acidic surface of activated carbon NaOH which is alkali can be adsorbed better than Na_2CO_3 . The other investigated result is the amounts of both NaOH and Na_2CO_3 adsorbed from mixture are lower than those could be adsorbed from single-solute solution. This result corresponds to the result from studying the adsorption of mixture of phenol and aniline by Kirichenko (31). This phenomena is simple to explain. For adsorption, the active surface area of activated carbon is important in controlling the amount of adsorbate adsorbed especially for monolayer adsorption. Both NaOH and Na_2CO_3 in the mixture can be adsorbed on the limited surface area that resulting less quantity adsorbed comparing to single-solute adsorption.

5.3 Effect of Variables on Cumulative Uptake of Solute on Activated Carbon (m) and Mass Transfer Rate (M)

5.3.1 Effect of Concentration of Solute

Fig 4.1a, 4.1b, 4.1c, 4.1d, 4.1e, 4.2, 4.3a, 4.3b, 4.4 show respectively cumulative uptake of formaldehyde, sodium hydroxide, sodium carbonate and the mixture of sodium hydroxide and sodium carbonate by activated carbon as a function of time for different concentrations. The total quantity of solute removed from solution at any period of time increased with increasing influent concentration. For example, from the adsorption of formaldehyde in Table B-1, after 1 hour of operation, the carbon in the experiment in which $C_0 = 0.328$ Molar had removed a total quantity of solute equal to approximately 0.60 gm/gm of activated carbon, and for $C_0 = 0.113$ Molar, the solute removed after the same period of time was about 0.21 gm/gm of activated carbon. The effect of concentration on the total quantity of solute removed from solution by the carbon accords well with that which would be anticipated on the basis of the increased driving force for transfer with increased concentration of solute in solution.

It is observed from Fig 4.2, 4.3a, 4.3b, 4.4 that the initial stage, m increases rapidly and is linearly with time. This result shows that the quantity adsorbed at the beginning is very important and may be explained by film diffusion. Film diffusion controls as the rate limiting step to the point at which the external surface area becomes essentially saturated. When time increases, the mass adsorbed causes thicker layers of adsorbate over the adsorbent and then causes decreasing mass transfer rate. The mass transfer will be occurred again after the mass

adsorbed is transferred into the internal surface of adsorbent but this step occurs slowly.

The relations of mass transfer rate (M) with concentration of solute shown in Fig 4.13., 4.14, 4.15 and 4.16 are corresponded to the relation of cumulative uptake with concentration. They confirm the validity of the relation in Eq(4.4). It is observed from table C-1, C-2, C-3, C-4 that mass transfer coefficients for different influent concentrations of solute have been found to be essentially equal over the range of influent concentrations studied. For the constant mass transfer coefficient, and surface area, the mass transfer rate increases linearly with increasing of concentration of solute.

5.3.2 Effect of Particle Size of Activated Carbon

The effect of particle size on cumulative uptake (m) for formaldehyde, NaOH, Na_2CO_3 and the mixture of NaOH and Na_2CO_3 are illustrated in Fig 4.5, 4.6, 4.7 and 4.8 respectively. The calculated values are shown in Table B-6, B-8, B-12 and B-15. It is observed that the total quantity of solute removed from solution at any period of time decreases with the increasing of the particle size of adsorbent. Since the surface area per unit weight of carbon increases for decreasing particle sizes, the film diffusion step which remains rate limiting in the initial can caused a little more adsorption for small particle sizes and more time is required to saturate the greater surface area.

The effect of particle size of activated carbon, expressed

in terms of diameter of particle, on mass transfer rate are plotted in Fig 4.17, 4.18, 4.19 and 4.20 for the adsorption of formaldehyde, sodium hydroxide, sodium carbonate and the mixture of sodium hydroxide and sodium carbonate respectively. It is observed that the transfer rate decreases with the increasing of particle size. This could be explained that for decreasing particle size the surface area per unit weight of carbon increases.

5.3.3 Effect of Feed Rate

The effects of feed rate on cumulative uptake of formaldehyde, sodium hydroxide, sodium carbonate and the mixture of sodium hydroxide and sodium carbonate are illustrated in Fig 4.9, 4.10, 4.11 and 4.12 respectively. The effect of flow rate on the solute uptake curves accords well with expected behavior. The effect of feed rate expressed in term of velocity, u on mass transfer rate are shown in Fig 4.21, 4.22, 4.23 and 4.24. It is observed that mass transfer rate, as the cumulative uptake of the solute, increased with the increasing velocity, u . Increasing flow rate this region may be expected to result in a compression or reduction of the surface film, thereby decreasing resistance to mass transfer.

Equation (4.4) indicates that for the postulated rate step the initial portion of a plot of adsorbate uptake per unit weight of adsorbent against time should approach linearity, with a slope of mass transfer rate $k SC_0$. Deviation from linearity occurred in the adsorption of formaldehyde at flow rate $1,260 \text{ cm}^3/\text{min}$

It might be explained that the deviation occurred because of the increasing influence of intraparticle transport on the overall rate of mass transfer.

5.4 Variation of Mass Transfer Coefficient with Some Variables

5.4.1 Effect of $1/S$

The relation between k and surface area is illustrated in Fig 4.29, 4.30, 4.31 and 4.32 for the adsorption of formaldehyde, sodium hydroxide, sodium carbonate, the mixture of sodium hydroxide and sodium carbonate respectively; where the surface area expressed in the term $1/S$. The graphical results demonstrate a linear dependence of the mass transfer coefficient on the reciprocal of the surface area. It could be explained by using the relation of the surface area and mass transfer coefficient expressed in Eq.(4.4) that $k = \frac{M}{C S}$. It was clearly shown in section 5.3.2 that the surface area^o of adsorbent decreases with the increasing of the size (d_p). And the increasing of surface area leads to the increasing of mass transfer rate and the increasing of S seemed to take important role than of transfer rate, M that the mass transfer coefficient, k in term of cm/hr shown in Eq.(4.4) increased with the decreasing of S , or the increasing of $1/S$. For increasing of S it seems to get a long time to saturate the surface area of activated carbon.

5.4.2 Effect of Re_p

In Fig 4.24, 4.26, 4.27 and 4.28 the values of k are plotted against the Re_p on log-log scale for the adsorption of formaldehyde, sodium hydroxide, sodium carbonate and the mixture of sodium hydroxide and sodium carbonate respectively. It is observed that k increases with the increasing of Re_p , and that Re_p is useful for the correction of mass transfer coefficients determined from the experiments with fluid-carbon columns under different conditions of flow rate and particle size which are both characterized in the dimensionless Re_p .

5.4.3 Effect of Influent Concentration

Mass transfer coefficients for different influent concentrations of solute shown in Table C-1, C-2, C-3 and C-4 have been found to be essentially equal over the range of influent concentration studied. Equation (4.4) shows that the mass transfer rate increases with the increasing of concentration of solute, it is expected, on the basis of mathematic model that for the same size of activated carbon the mass transfer coefficient should be equal over the range of influent concentration. This relation corresponds to that of Weber (27).