CHAPTER I

INTRODUCTION

Industrial exhaust gases from gas mixtures of volatile organic compounds (VOCs) is one of the major air pollution problems. The vapors of acetone, alcohol, toluene, xylene, etc. are found in the industries for solvent degreasing graphic arts manufacturing, surface coating application in furniture manufacturing including in car assembly factory and garage. These vapors have the potential hazards to human health and they are flammable. The maximum allowable concentrations of toluene and xylene vapors in air based on the American Gas Association standard are 200 ppm.

Many separation processes, such as absorption, adsorption, membrane separation and thermal and catalytic incineration, can be used to control the emission of hazardous air pollutants. Each process has demonstrated advantages and disadvantages. Selection of an appropriate separation technology depends on the specific details of the emission streams, site-specific constraints that may inhibit or prohibit uses at a given location, specific control efficiency and economic considerations.

In gas absorption a soluble vapor is absorbed from its mixture with an inert gas by mean of a liquid in which the solute gas is more or less soluble. A common apparatus used in gas absorption is the packed tower. The diameter of a packed absorption tower depends on the quantities of gas and liquid handled, their properties, and the ratio of one stream to the other. The height of the tower and the total volume of packing depend on the magnitude of the desired concentration changes and on the rate of mass transfer per unit of packed volume (McCabe, 1985). Therefore, it needs large unit to get high efficiency.

Membrane processes separate the components of a gas or liquid mixture on the basis of their relative permeation rates through a membrane material. Important commercial applications of membrane processes include the separation of air to produce nitrogen, and the recovery of hydrogen from hydrocarbon gas streams. The weaknesses of membrane processes are fouling and the lack of durability of membrane materials. Additionally, capital costs for membrane units often are too high to compete with other processes, particularly at higher volumes (Humphrey, 1995).

Thermal and catalytic incinerators have been used for VOC control for decades. Incinerators rely on high temperatures, long residence times, and good turbulence between the gas stream containing organic compounds and oxygen in the combustion chamber to provide for the permanent destruction of the organics. However, both thermal and catalytic incinerators have certain perceived disadvantages. These include the generation nitrogen oxides (NO_x) during high-temperature combustion, slow thermal response, and the general inability to handle chlorinated materials satisfactorily (McInnes, 1995).

The adsorption process has been widely used because of its flexibility. The operation depends on at least one of the components of the gas mixture being adsorbed more strongly than the others at equilibrium. The efficiency of adsorption can be developed by using the appropriate adsorbents and more efficient adsorption operation. A variety of materials are used as adsorbents. These include activated carbons, silica gel, activated alumina, carbon molecular sieves and zeolite molecular sieves. Activated carbon has been widely used to control VOCs in a variety of industries but it has the limitations, particularly where the VOC-laden stream requiring control is hot (above 40 °C) or saturated with moisture (McInnes,1995). In addition, activated carbon has a wide range of pore size distribution and it is difficult to regenerate. As a result of these limitations, new adsorbents have been developed.

Zeolite becomes interesting for separation process because of its strictly regular crystalline structure, all pores are essentially the same size. Thus, a bed of zeolites functions like a molecular sieve which captures the small molecules that fit into its pores while the large molecules pass through the bed. In addition, the degree of polarity of zeolite is another important adsorptive property.

The adsorption of aromatic hydrocarbons on zeolites have been studied by many research groups using different experimental techniques. Pope (1984, 1986) determined the thermodynamic properties of the adsorption of benzene, toluene and p-xylene on silicalite and ZSM-5. Shah et al. (1988) measured equilibrium sorption capacity and diffusion rate of benzene in ZSM-5 and Guo et al. (1989) measured adsorption equilibrium of benzene in silicalite by using gravimetric method. Choudhary and Srinivasan (1987) measured sorption isotherm of benzene in HZSM-5 at catalytic conditions using gas chromatographic sorption/desorption technique. Multicomponent adsorption equilibria of xylene mixtures on zeolite K-Y were studied by Paludetto et al. (1987). Their system was operated on the principle of displacement chromatography. Gamba et al. (1990) reported the adsorption equilibrium data of single component, binary and ternary mixture of aromatic hydrocarbons on K-CaX . After that, Li and Talu (1994) measured the adsorption equilibrium of benzene - p-xylene vapor mixtures on silicalite with a cyclic volumetric apparatus.

The diffusion data of benzene and xylene on ZSM-5 and silicalite were shown by Chiang et al. (1984). Rees and Shen (1992) measured the frequency response of diffusion of benzene in HZSM-5, silicalite-1 and NaX. Xiao and Wei (1992) studied the diffusion mechanism of benzene and toluene in ZSM-5 by using a Cahn 2000 vacuum electrobalance to determine the transient uptake of diffusing molecules. The theory for predicting surface diffusion was proposed by Chen and Yang (1992). They compared with the experimental data of pure component and binary diffusion of benzene-toluene in ZSM-5 and also reported the heat of adsorption. Recently, Masuda et al. (1996) measured the intracrystalline diffusivities in Y type zeolite for four aromatics : benzene, toluene, ortho and para-xylene by a conventional constant volume method.

However, sometimes the reported data do not show the same consistency. The diffusivities measured by different research groups, by different methods for the same system differ each other several orders of magnitude.

The chromatographic technique was used to measure the adsorption equilibrium constant and adsorption rate constant from chromatogram by the method of moments. Schneider and Smith (1968), Carleton (1978), Kershenbaum and Kohler (1982) and Hufton and Danner (1993) used this technique to determine the adsorption equilibrium constant and rate of diffusion of alkanes in various adsorbents.

The objective of this research is to compare the adsorption ability of several molecular sieve zeolites to adsorb toluene and ortho-xylene vapors by considering the adsorption equilibrium constant of zeolites in the following groups :

- Study the effects of binder by comparing the adsorption abilities of commercial 4A (including binder) and synthesized 4A (without binder)

- Study the effects of structure of zeolites by comparing the adsorption abilities of NaZSM-5, 4A, and 13X

- Study the effects of types of cations by comparing the adsorption abilities of NaZSM-5, NH_4ZSM-5, and HZSM-5.

In addition, mass transfer coefficient and heat of adsorption are considered to select the appropriate adsorbents.