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Equilibrium and kinetics Studies of Adsorption of Heavy Metals onto Activated Carbon

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Abstract — *Heavy metal ions are toxic pollutants. The contamination of water by toxic metals is a world-wide environmental problem. This paper studies the adsorption isotherm of heavy metals named Pb(II), Cu(II), Cr(III) and Co(II) ions from aqueous solution onto activated carbon. The results show that activated carbon can be used as an adsorbent for the removal of heavy metals. The amount of metal ions adsorbed increases with increasing the initial metal ions concentration. Six adsorption isotherm models were used to analyze the experimental data. Radk- Prausnitz, Langmuir isotherm, Redlich-Peterson and Sips isotherm models gave the best fit with the correlation coefficient, R2, value ranging from 0.999 to 0.978 (Ave. 0.993). This is followed by Freundlich isotherm (Ave. 0.971) and Temkin isotherm (Ave. 0.937). The kinetics of these metal ions adsorbed onto activated carbon was analyzed using pseudo-first order and pseudo-second order. Results were found to follow pseudo-second order equation*

Key Words — Adsorption Isotherm, Adsorption kinetic; Activated carbon; Heavy metals.

1. INTRODUCTION

Heavy metals pollution is an important environment problem because of their toxicity and threat to human life and to environment. Therefore the elimination of heavy metals from water and wastewater is important to protect public health.

According to the World Health Organization (WHO, 1984) the most toxic metals are aluminum, chromium, cobalt, nickel, copper, zinc, cadmium, mercury and lead. The main sources of toxic metals are industrial wastes from processes such as electroplating, metal finishing, and chemical manufacturing (Abdel-Halim et al., 2003).

A number of treatment methods for removal of heavy metals from industrial wastewater include chemical precipitation, ion exchange, membrane separation, and adsorption. Among them adsorption process is found to be the most effective method for removing dissolved metal ions from wastes (Aalam et al.,2004). Activated carbon has been widely used as an adsorbent with great success (Chand et al., 1994; Mckay, 1982; Aluyor and Oboh, 2009). Previous studies have showed that activated carbon also can remove heavy metals in water treatment (Aluyor and Oboh, 2009; Jusoh et al., 2007; Khalkhali and Omidvari, 2005; Gheju and Miulescu, 2008).

The analysis and design of an adsorption process require the adsorption equilibrium which is the most important piece of information in the understanding of the adsorption process (Vasanthand and Sivaneson, 2006). Equilibrium studies that give the capacity of the adsorbents for the adsorbate are described by adsorption isotherm, which is usually the ratio between the quantity adsorbed and the remaining in the solution at equilibrium and at fixed temperature (Ho, 2006; Jgwe and Abia, 2007). The various adsorption isotherm equations have been used to study the nature of adsorption such as Langmuir, Freundlich, Redlich-Peterson, Sips, Temkin and Radk-Prausnitz, isotherm models. The most commonly used isotherm models include Langmuir, Freundlich and Redlich-Peterson (Subramanyam and Das, 2009). The kinetics of adsorption depend on the adsorbate concentration, the physical and chemical characteristics of the adsorbent. The adsorption kinetics describe the solute uptake rate which in turn governs the residence time at adsorption reaction. It is one of the important characteristics in defining the efficiency of adsorption process (Rengaraj and Moon, 2002).

The aim of this work is to study equilibrium and kinetics of adsorption of Pb(II), Cu(II), Cr(III) and Co(II) onto activated carbon. Six isotherm models were used to analyze the experimental data. The kinetic experimental data were tested for two kinetics equations, pseudo first-order and pseudo second-order equations.

2. EQUILIBRIUM ISOTHERM STUDIES

The analysis of the equilibrium adsorption isotherms data are important to study the adsorption capacity and equilibrium coefficient for adsorption, also it is important in developing accurate data that could be used for adsorption design purpose. In the present study six adsorption isotherm were utilized: Langmuir, Freundlich, Redlich-Peterson, Sips, Temkin and Radk-Prausnitz isotherm models.

Langmuir isotherm model is probably the best known and most widely applied sorption isotherm. It has produced a good agreement with a wide variety of experimental data. The Langmuir isotherm is applied to homogeneous sorption (Ho, 2003; Subramanyam and Das, 2009). It is the simplest theoretical model for monolayer adsorption which was developed from either kinetic derivation or thermodynamic derivation (Ruthven, 1984). This model is developed by