Shape-Selective Adsorption of Substituted Aniline Pollutants from Wastewater

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ABSTRACT: ZSM-5 zeolite was used to treat wastewater containing aniline, 2-nitroaniline (2-NA), 3-nitroaniline (3-NA) and 4-nitroaniline (4-NA). Each molecule was removed from aqueous solution by Type I Langmuir adsorption onto ZSM-5. The quantities adsorbed varied greatly due to their shape-selective adsorption within the pores of ZSM-5. Aniline and 4-NA had maximum adsorption amounts of 161 and 265 mg g^{-1}, respectively, while the maximum amounts of 3-NA and 2-NA were 94.3 and 37.2 mg g^{-1}, corresponding to reductions of 64% and 86%, respectively, relative to 4-NA. This outcome was caused by the increase in the effective diameter for adsorption when the nitro group was located at the 2- and 3- positions of the molecule. This significantly reduced their ability to enter into, and diffuse through, the pores of ZSM-5. These findings underpin the importance of choosing the correct substrate when using such materials for water purification.

1. INTRODUCTION

Aniline, 2-nitroaniline (2-NA), 3-nitroaniline (3-NA), and 4-nitroaniline (4-NA) are highly toxic, carcinogenic species that are widely used in azo dyes, paints, pharmaceuticals and agrochemicals (Damborsky and Wayne Schultz 1997; Bhunia *et al*. 2003; Wang *et al*. 2008). Aniline, for example, causes the transformation of haemoglobin to methaemoglobin, which has a lower affinity for oxygen than haemoglobin, and therefore reduces blood's ability to transport oxygen. All four compounds are soluble in water, and therefore their inclusion in industrial wastewater streams, and subsequent assimilation into groundwater aquifers, pose a significant threat to human health. The structures of these compounds are shown in Figure 1.

A number of techniques, including oxidation, membrane separation and biodegradation have been used to remove such harmful compounds from water (Lee *et al*. 1997; Saupe 1999; Williams *et al*. 1999; Judd and Jefferson 2003; Gautam *et al*. 2005; Qureshi *et al*. 2007; Sun *et al*. 2007). Organic pollutants may also be removed from aqueous solution by adsorbing them onto solid substrates. Such systems are particularly favourable because the pollutant is easily separated from the purified water by filtration of the pollutant-loaded solid adsorbent. Activated carbons (Derylo-Marczewska and Marczewski 2002; Li *et al*. 2009a, b), polymer resin (Zheng *et al*. 2007), clays (Ko *et al*. 2007) and mesoporous oxides (Bibby and Mercier 2003; El-Safty *et al*. 2012) have been used as adsorbents of various aniline-type compounds. Zeolites are high-surface area inorganic materials that have been used in areas such as

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