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REVIEW

Competitive adsorption of heavy metals on local landfill clay

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Abstract The aim of this study is to investigate the interaction of Cr^{III} and Cd^{II} ions in solution with the local landfill clay of Jebel Chakir (Ghorbel-Abid et al., 2009) located in the northwest of Tunis (Tunisia, North Africa). The adsorption properties of natural clay and the Na-purified clay in a chromium and cadmium rich aqueous solution have been studied by batch technique. The amount of adsorbed heavy metals ions, Q_e, was determined for the adsorption systems as a function of the contact time, the pH, and the metal ion concentration. The results show that the uptake of Cr^{III} by the purified clay is very fast. The quantity removed from the solution reached a maximum value 15 min after mixing, for the purified clay, and 1 h for the natural clay, although the latter removes greater quantities of Cr^{III} ions compared to the Na-purified clay. However, the uptake of Cd^{II} reached its maximum value approximately 2 h after mixing, for the purified clay, and 3.5 h for the natural clay, although the removed quantities of Cd^{II} ions are comparable in both the Na-purified and natural clay.

The experimental data points have been fitted to the Langmuir and Freundlich models. The competitive adsorption isotherms of Cr^{III} and Cd^{II} ions in similar conditions have been studied by the batch technique. The amount of adsorbed ions, Q_e was determined. The results show that the presence of Cd^{II} has an important effect on the uptake of Cr^{III}.

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1. Introduction

For decades, urban and industrial pollution has led to a gradual environmental degradation of the natural environment (atmosphere, water or soil). This phenomenon is serious and requires great efforts to correct the situation and prevent its proliferation. That is why the scientific knowledge of the contamination process is paramount. Demographic and economic changes in consumption patterns of Tunisia's residents resulted in an increase in the volume of household wastes to 1,800,000 metric tons per year (0.5 kg/person/day) with an annual growth rate production of 2% (ANPE-PRONAGDES, 2005). This required the creation of controlled landfills for household and similar wastes in the urbanized areas. Such landfills are adding to the environmental degradation which needs to be contained and redressed before it becomes irreversible.

Clays have been evaluated for their purifying qualities since they are thought to act as a filter and purifier of pollutants (Ghorbel-Abid et al., 2009, 2010; Coetzee et al., 2003; Bailey, 1999; Chakir et al., 2002; Ayari et al., 2005, 2007a,b; Vegal et al., 2005; Kaya and Hakan, 2005; Ramesh et al., 2007; Bellir et al., 2005; Yavuza et al., 2003; Abollino et al., 2003; Auboiroux et al., 1996; Barbier et al., 2000). Given their high impermeability, clays are often used as pollution barrier for waste storage sites (Bellir et al., 2005; Kouamel et al., 1970). In most cases, the nature of clay that seals the site floor is a criterion for selecting the landfill site.

The evolution process of waste degradation led to the production of leachates.

The composition of leachates is highly variable from one discharge to another depending on waste composition.The chemical composition varies in a quasi-permanent pattern due to the complex nature of waste into rich organic and inorganic pollutants, especially heavy metals. Moreover, the composition of leachates changes over time due to the evolution process of waste degradation which is strongly linked to the physico-chemical and biological processes occurring in the landfill. Researchers (Coetzee et al., 2003) have studied the geochemical mechanisms that govern the vertical migration of some heavy metals to assess the risk of contamination of water by metals from the landfill leachates. The geochemical processes that govern the vertical migration of heavy metals indicate that adsorption is the dominant mechanism. The alkaline (7–10) and slight acidity (6–7) pH of the medium have a significant influence on the chemical form of metals and seem to favor the adsorption mechanism. Although the presence of heavy metals does not cause immediate danger to the population, it can lead to sustained, irreversible or wider contamination of the environment. This in turn could lead to long-term contamination of the surrounding soil and groundwater. The landfill in Jebel Chakir (north-west of Tunis), which received 7 M metric tons of waste in 2009, is the case we studied in this research.

We have focused our adsorption study on two heavy metals: cadmium and chromium, given their dangerous impact on heath and the environmental future of the site, and their significant presence in the leachates from the decomposition of solid waste landfill of Jebel Chakir. Their concentrations may reach 0.02 mg L^{-1} and 3.30 mg L^{-1} for cadmium and chromium, respectively. Cadmium is one of the few elements with no known function in human or animal life. However, its toxicity is known in all its forms (metal, vapor, salts, inorganic and organic compounds). For chromium, the chemical and toxicological properties are significantly different depending on the concentration and valence state it happens to be in.

Since the study of adsorption of heavy metals in leachates on clay in real conditions is difficult because of the complexity of the system involved, we resorted to studying synthetic systems using solutions containing one or both of these cations (Cd^{II}, Cr^{III}) and the natural or purified clay fractions.

2. Experimental set up

2.1. Materials

Local clay from Jebel Chakir has been characterized in an earlier study (Ghorbel-Abid et al., 2009). The chemical compositions in weight percentage for the raw material denoted as JCKb, and for the Na-purified clay denoted as JCKp are given in Table 1. Heavy metals are present in the natural and the purified clays in a trace amounts.

The cation exchange capacities (CEC) as well as the total internal plus external surface areas (SSA) were determined