



Research paper

A natural clayey adsorbent for selective removal of lead from aqueous solutions



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ABSTRACT

Natural clay minerals are an inherently colorless class of materials, which have long been known for their versatility as adsorbents due to their interchange capacity, large catalytic support, great surface area, and low cost. Herein, we have reported the use of natural clay, collected from the Gabes area, southern Tunisia (Early Cretaceous) for selectively capturing of lead ions from aqueous environments. Our results showed that natural clay samples were mainly composed of silica, alumina, iron and magnesium oxides. Adsorption data showed that the studied clay samples preferably removed substantial amounts of lead ions from water. The removal efficiency of lead ions was about 86.4 mg/g of clay and followed pseudo-second-order kinetics. More than 95% of the total adsorptive capacity occurred within 30 min. These results suggest the Early Cretaceous clays, Tunisia, turned out to be an effective natural adsorbent for capturing of lead ions from aqueous environment.

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1. Introduction

The discharge of heavy metal ions into municipal sewers by mining, metallurgical, electroplating, electronic, nuclear and other industries constituents became a serious threat to human health and the environment (Kim et al., 2012). Therefore, great efforts have been devoted to control monitoring and removal of heavy metals from the environment has been a very active research area in recent years (Yang et al., 2013). Among all the heavy metal ions, lead ion (Pb^{2+}) is one of the most toxic pollutants in drinking water and surface soil; it may be accumulated in the human body as a potential neurotoxin that causes bone and kidney damage. Lead ions are often encountered in the environment due to its use in batteries, gasoline, and pigments, as the 300 million tons of lead mined to date are still circulating mostly in soil and groundwater (Boudrahem et al., 2011). The permissible level for lead in drinking water is 0.05 mg/L according to the US Environmental Protection Agency (EPA). Thus, the removal of lead ions from environment is very critical. A number of technologies have been developed for removal and recovery of metal ions including filtration, chemical precipitation, ion exchange adsorption, electrodeposition and membrane systems (Khairy et al., 2014). Among all these technologies, adsorption is widely used for removal and recovery of metal ions due to its simplicity of

equipment and operation, and the possibility of using a solid adsorbent for numerous extraction cycles without losses in the metal extraction capacity (El-Safty et al., 2015). Therefore, extensive efforts have been devoted to research and characterize new adsorbents for specific metal ions with high removal capacities.

Activated carbon is the most popular and widely used adsorbent for adsorption of metal ions, however, it is expensive (Ballav et al., 2014). Therefore, there is a growing interest in using low-cost, easily available materials for the adsorption of metal ions. Natural clay has attracted much attention due to its large catalytic support, large surface area, mechanical stability, and low cost which make it a promising adsorbent. Clays can be divided into two main classes: cationic clays that have negatively charged alumino silicate layers; and anionic clays, with positively charged hydroxide layers. The neutrality of these materials is ensured by ions, cations, or anions, depending on the clay type, in the interlayer space that balances the charge.

Herein, we report simple, economical and ecofriendly strategy for capturing and removing lead ions from aqueous solutions. In fact, natural clay served as matrix for active ions and usually able to incorporate ions by an ion-exchange process, like polymeric ionomers. In this study, natural clay was used as a matrix for the removal of lead ions from aqueous solutions. The studied clay sample was simply treated with acetic acid and hydrogen peroxides to remove carbonate and organic matter, respectively. It was composed of high amounts of SiO_2 , Al_2O_3 and Fe_2O_3 , indicating typical clay deposits of the Early Cretaceous, southern Tunisia (i.e., “Wealden” facies). These compositions showed

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ionic interchange capacity and great surface area ($50 \text{ m}^2/\text{g}$), particularly in the presence of iron oxide. The iron oxide as magnetic material offered a large exposed surface area without using its porous network, which is plagued often by high mass transfer resistances. Simple batch adsorption method was performed by mixing clay sample with a different metal ion solutions under pH of 6. The effects of pH, contact time, and lead (II) ion concentrations were investigated, as well. The adsorption isotherm, and kinetic parameters were deduced from the adsorption measurements. Our experimental results showed higher capability of natural clay to capture lead ions (86.4 mg/g) from aqueous solution of pH 6. These results suggest that Late Cretaceous clays, Tunisia, can be effectively used for selective removal of lead ions in aqueous systems. The innovative aspect of the present study was the

identification of natural adsorbent for selective lead ions from aqueous solutions.

2. Geological settings

The studied area belonged to the southern Tunisian Atlas; in the northern edge of Saharan platform where it showed complete Cretaceous sequences. Nearby the Chotts anticline, the sedimentary series extended from the Lower Cretaceous to the Quaternary (Fig. 1).

Thus, the southernmost Atlas of Tunisia offers significant outcrops of argillaceous formations attributed to the Cretaceous and Cenozoic periods. These formations revealed different levels of smectites, illite and kaolinite. Numerous researchers including Bouaziz et al. (2007);

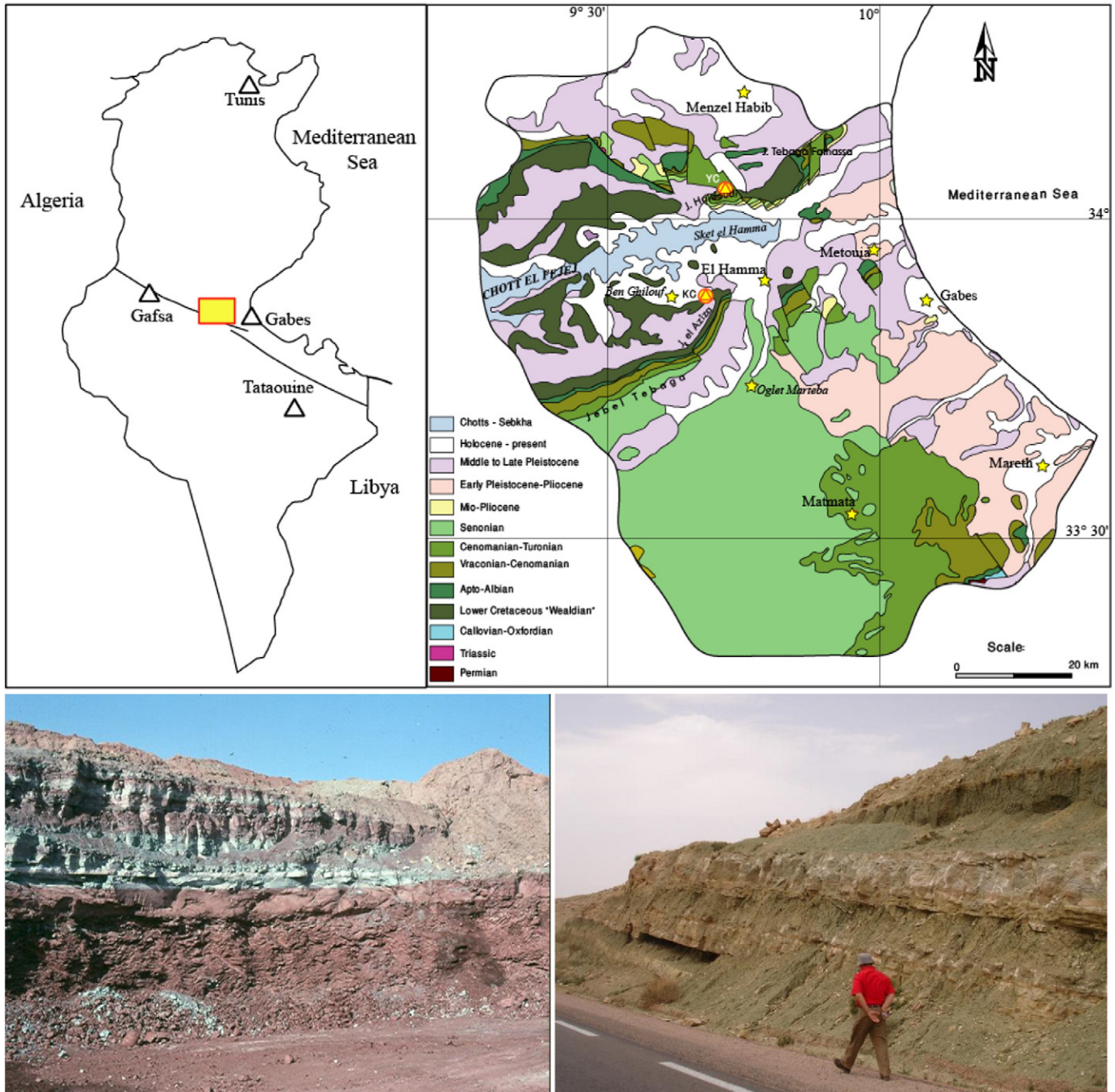


Fig. 1. Geological map of the Gabes area showing the distribution of the Low Cretaceous "Wealden facies" and location of the collected sample. Modified after Chaabouni et al. (2012).

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