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FULL LENGTH ARTICLE

Removal of aluminum, iron and manganese ions from industrial wastes using granular activated carbon and Amberlite IR-120H

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Sorption capacity

Abstract The removal of aluminum, iron and manganese from some pollution sources that drain into Ismailia Canal has been investigated using two different sorbents; granular activated carbon (GAC) and Amberlite IR-120H (AIR-120H). Batch equilibrium experiments showed that the two sorbents have maximum removal efficiency for aluminum and iron pH 5 and 10 min contact time in ambient room temperature, while pH 7 and 30 min were the most appropriate for manganese removal. Dosage of 2 g/l for both GAC and AIR-120H was established to give the maximum removal capacity. At optimum conditions, the removal trend was in order of $Al^{+3} > Fe^{+2} > Mn^{+2}$ with 99.2, 99.02 and 79.05 and 99.55, 99.42 and 96.65% of metal removal with GAC and AIR-120H, respectively. For the three metals, Langmuir and Freundlich isotherms showed higher R^2 values, with a slightly better fitting for the Langmuir model. In addition, separation factors (R_L) and exponent (n) values indicated favorable Langmuir ($0 < R_L < 1$) and Freundlich ($1 < n < 10$) approach. GAC and AIR-120H can be used as excellent alternative, effective and inexpensive materials to remove high amounts of heavy metals from waste water.

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Introduction

In Egypt, the pollution by trace metal ions is one of the most serious environmental problems. Effluents, resulting from daily domestic and industrial activities may induce considerable changes in the physical and chemical properties of Nile water. These changes may greatly alter the environmental characteristics of river reaches (El-Sayed, 2011).

Unlike many organic wastes, heavy metals cannot be degraded biologically into harmless products. As a result, heavy metals tend to accumulate in the food chain and environment (Huang et al., 1991). Most of the heavy metals are bound to particles in sediment, but only a small quantity becomes dissolved in the water and it can spread widely in the food chains (Khadr, 2005). Heavy metal contamination exists in the aqueous waste streams of many industries like,

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metal plating, mining operations, metal smelters, microelectronics, radiator, alloy, storage battery, plastics and textiles manufacturers, wood preservatives producing industries, as well as agricultural sources where fertilizers, pesticides and fungicidal spray are intensively used (Bhatti et al., 2007; El-Ashtoukhy et al., 2008; Hegazi, 2013).

Wastes that contain metals are considered to be hazardous to both human life and the environment due to their acute toxicity and non-biodegradability, even when the heavy metals are present at trace concentrations (Zhang et al., 2005). Heavy metal ions can be accumulated by aquatic organisms that would then endanger human health through the food chain (Singanan, 2011). They accumulate in living tissues throughout the food chain where humans are at its top. Their accumulation over time causes damage to the kidney, liver, nervous system, reproductive system in addition to cancer nervous system (Malik et al., 2010) and brain damage if found above the tolerance levels (Brown et al., 2000).

Removal of toxic heavy metals from the environment is an important challenge. Several methods for removal of metal ions from waste waters have been developed. A removal process must be simple, effective and inexpensive (Ahn et al., 2008). Several processes have been suggested to remove heavy metals from wastewaters, such as chemical precipitation, ion exchange, cementation, coagulation and flocculation, complexation, biosorption, adsorption, and membrane processes (Ahn et al., 2009; Xiong et al., 2009). However, most removal processes have disadvantages, such as continuous input of chemicals, high costs and even incomplete metal removal (Minceva et al., 2007).

Adsorption is a very effective process for a variety of applications, and is considered economical and widely applicable. It creates relatively little sludge and is an efficient method for metal ions removal from wastewaters (McKay, 1996; Kannan and Rengasamy, 2005). The most generally used solid adsorbent is activated carbon, which is used as a very efficient solid adsorbent in many different applications (Cooney, 1998). Activated carbon is the carbon produced by activation of any carbonaceous material such as coconut shells, bamboo, wood chips, sawdust, coal, lignite, paddy husk, etc. Activated carbon is a black, solid, powdered, granular, microcrystalline or a pelletized substance non-graphitic form of carbon with an excessively porous material and a large internal surface area, which is known for its high capacity to bind contaminants by adsorption (El-haddad, 2012). Activated carbon can be characterized by a large specific surface area of 500–2500 m^2/g, this is its most important physical property, which allows the physical adsorption of gases or vapors and dissolved or dispersed substances from liquids (Kadirvelu et al., 2001; Bansode et al., 2003). Activated carbon removes heavy metals by complexation or by electrostatic attraction of metal ions to various surface oxygen-containing functional groups (Yin et al., 2007).

Another effective method used for the removal of heavy metals is ion exchange. Ion exchange may be defined as the exchange of ions between the substrate and surrounding medium. Ion exchange is one of the most frequently studied and widely applied techniques for the treatment of metal-contaminated wastewater and the renewal of solutions for reusing, in addition to recovery of metallic substances (Lee et al., 2007). Ion exchange resins are usable at different pH values and suitable at high temperatures. Ion exchange is insoluble in most organic and aqueous solutions. They contain a covalent bonding between the charged functional groups and the cross linked polymer matrix (Sherrington, 1998). The ion exchangers are classified into anion and cation exchangers, which contain anions or cations as oppose-ions, respectively. The cation and anion exchangers are categorized into strongly acidic, weakly acidic, strongly basic, weakly basic ion exchanger based on nature of functional groups (Hubicki and Kolodynska, 2012).

In the present study two sorbent substances, granular activated carbon (GAC) and Amberlite-IR-120H (AIR-120H), were used to remove some metal ions from industrial waste, which discharged into Ismailia Canal. Ismailia Canal is one of the most important branches of Nile River in Egypt with about 128 km length from Cairo to Ismailia governorate. It is the main source of drinking and irrigation water for many governorates, cities and villages (Goher et al., 2014).

The main objective of this study was to remove metals from aqueous solutions, as well as to remediate high metal content wastes, which were discharged into Ismailia Canal using granular activated carbon and strongly cationic exchanger Amberlite-IR-120H. A detailed investigation on the effect of pH, contact time and dosage on metal removal from a mixed solution of three metals was carried out. Isotherm studies were used to quantify the adsorption process. Comparing equilibrium studies was performed using GAC and AIR-120H.

Materials and methods

Preparation of metal solutions

Industrial waste water samples from some source of pollution that is effluent to Ismailia Canal, Egypt, were collected in February-2014. They were preserved and analyzed for metals contents following standard method procedures (APHA, 1998). 1000 mg/l of metal solutions of aluminum, iron and manganese from Sigma–Aldrich analytical grade were used to prepare the mixed synthetic solutions. The initial total metal ion concentration, used in the adsorption equilibrium experiments, was prepared in the laboratory based on metal concentration in the industrial effluent.

Adsorbent

The granular activated carbon (GAC) and Amberlite-IR-120H (AIR-120H), which were used as sorbents in this study were bought from Dohrmann Company and Rohm and Hass company respectively. The characteristics of GAC and AIR-120H are shown in Tables 1 and 2 respectively.

The specific surface area and pore volume of the GAC were measured by Quantachrome instrument model NOVA 3200

Table 1 Physico-chemical properties of GAC.

Physical properties		Elemental analysis	%
Ash content	10 (%) max	C	82.23
Bulk density	0.813 g/m^3	Mo	6.16
Density	49 g/cm^3	Ag	4.46
Surface area	688.6 m^2/g	Cl	3.68
Total pore volume	0.3445 cc/g	S	0.19

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