Investigation on the sorption of aluminium in drinking water by low-cost adsorbents

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Abstract

Aluminium is one of the trace inorganic metals present in drinking water. High aluminium concentrations (3.6 to 6 mg/ℓ) may precipitate as aluminium hydroxide affecting aquatic life. Aluminium is also a suspected agent of neurological disorders such as Alzheimer's disease and senile dementia. The present investigation aims at the sorption of aluminium from drinking water using a low-cost adsorbent. Rice husk char and activated rice husk char were prepared and characterised for various physicochemical properties. The performance of rice husk char (RHC) was compared with other low-cost adsorbents for their aluminium removal capacity. The effect of pH, initial concentration, contact time and temperature was studied for adsorption of aluminium from water under batch conditions. The maximum adsorption capacity was observed with rice husk char at an optimal pH of 4.2. The adsorption of aluminium follows the Freundlich adsorption isotherm. The rate of aluminium adsorption was successfully described by a first-order kinetic model. The thermodynamic study revealed that aluminium adsorption is an exothermic process and the adsorption decreases with an increase in temperature.

Keywords: aluminium adsorption; batch; kinetics; thermodynamics; rice husk char

Nomenclature

b	Langmuir constant (ℓ/mg)
C_e	Equilibrium aluminium concentration in solution (mg/ℓ)
Ct	Aluminium concentration in solution at time t (mg/ℓ)
ΔG^o	Gibb's free energy (kJ/mol)
ΔH^o	Enthalpy change (kJ/mol)
K	Freundlich constant ($mg^{1-1/n}/g\ ℓ^{1/n}$)
k_1	First-order rate constant (per hour)
k_2	Pseudo second-order rate constant (g/mg·h)
n	Freundlich constant (dimensionless)
Q	Langmuir constant (mg/g)
q_e	Amount of solute uptake per unit mass of adsorbent at equilibrium (mg/g)
R	Gas constant (J/mol·K)
ΔS^o	Entropy change (J/mol·K)
T	Temperature (K)
t	Time (h)

Introduction

About 8% of the earth's crust consists of aluminium. This element is the most abundant metal naturally present in air, soil and water. Consequently, environmental exposure to aluminium is potentially possible. Its ingestion is unavoidable since aluminium compounds are added not only to most water supplies but also to many processed foods and medicine (Denizli et al., 2003).

Aluminium-based coagulants such as aluminium sulphate ($Al_2(SO_4)_3$) or poly-aluminium chloride are commonly used in drinking water treatment to enhance the removal of particulate matter, colloidal, and other dissolved substances via coagulation processes. The use of alum as a coagulant for water treatment often leads to higher concentrations of aluminium in the treated water than in the raw water itself (Srinivasan et al., 1999 and Srinivasan and Viraraghvan, 2002). Typically, a portion of the alum added to the raw water is not removed during treatment and remains as residual aluminium in the treated water. The occurrence of aluminium in treated water has been considered to be an undesirable aspect of the treatment practice (Letterman and Driscoll, 1988; Van Benschoten and Edzwald, 1990). There is considerable concern throughout the world over the levels of aluminium in drinking water sources (raw water) and treated drinking water.

Although a substantial amount of research work is needed before the full implication of the toxic aspects of aluminium are known, it is generally argued that the knowledge of the form and type of species of aluminium in water is of importance since both bioavailability and toxicity are critically dependent on the chemical form of the individual species. A high (3.6 to 6 mg/ℓ) concentration of aluminium in treated water gives rise to turbidity which reduces disinfection efficiency, and may precipitate as $Al(OH)_3$ during the course of distribution (Rahman, 1992). These elevated levels of aluminium may have serious ramifications for the fish living in these waters as well for some birds whose diets are made up of insects from the shoreline of affected streams and lakes (Miller et al., 1994). Aluminium is also a known neurotoxicant. It enters the brain, where it contributes to the dialysis encephalopathy syndrome and may contribute to Alzheimer's disease and other neurodegenerative diseases. Aluminium also gives rise to toxicity in the bones and haematopoietic systems in humans (Schecher and Discroll, 1988).

Because of its harmful nature and ill effects, different regulatory agencies have set their own standards for the levels of aluminium in drinking water. The World Health Organisation (WHO) has proposed a guideline value of 0.2 mg/ℓ. The present drinking water standard for aluminium in the US is 0.2 mg/ℓ

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