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Research Paper

Application of guar gum for the removal of dissolved lead from wastewater

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ABSTRACT

Lead (Pb) is a toxic heavy metal with highly recalcitrant property. It easily accumulates in the food chain by interacting with calcium and iron components of the biomolecules of living organisms. The aim of the study was to develop an efficient method to treat heavy metal containing turbid wastewater without the introduction of any secondary source of pollutants. Guar gum, a long chain polysaccharide was used to remove Pb^{2+} from turbid wastewater containing kaolinite. Guar gum is extracted from the seed of leguminous shrub Cyamopsis tetragonoloba commonly known as guaran. Potassium alum, a commonly used inorganic coagulant was also studied in order to compare its Pb^{2+} removal efficiency with the biopolymer. It was observed that guar gum could achieve 83% removal, at an initial Pb concentration of 15 mg L^{-1}. Optimization study using response surface methodology was used to determine the optimal process parameters. FTIR and zeta potential measurement of guar gum-Pb^{2+} aggregates were used to determine the removal mechanism. FTIR absorption peaks at 3618.79 cm^{-1} in the flocs indicate hydrogen bonding between Pb^{2+} and guar gum. Compact and well-formed flocs by guar gum are indicated by the SEM micrographs. In addition to the formation of compact sludge, guar gum is nontoxic and biodegradable and hence highly recommended for treatment of metal containing wastewater. The requirement of ultra-low amount of biopolymer in the range of 1.25 mg L^{-1} to treat the relatively high volume of water provides an additional financial advantage.

1. Introduction

Lead is a post-transition metal with high toxicity, affecting the central nervous system, liver, kidney and basic cellular processes and brain function in human beings (Fu and Wang, 2011). Elemental lead has been used for thousands of years by human beings. Pb found its way into the atmosphere and the aquatic systems through combustion of fossil fuels, smelting of sulphide ore and through into acid mine drainage (Gupta et al., 2001). The use of lead in manufacturing processes is being phased out from the beginning of the 20th century; however, lead acid battery industry remains one of the largest users of lead in its end product. The survey of some storage battery factories showed that the pH of the wastewater ranged between 1.6–2.9 and that the soluble lead in the wastewater was in the range of 5–15 mg/L (Bahadir et al., 2007). The recycling of lead acid batteries also generates large quantities of heavy metal containing wastewater. Lead is highly reactive and easily finds its way into the living systems by interacting with calcium, iron, and zinc (Goyer, 1997). Therefore, removal of Pb from wastewater is essential.

Removal of heavy metals from wastewaters can be achieved by various chemical, biological and physicochemical processes (Fu and Wang, 2011; Fu et al., 2012; Tang et al., 2014; Wan Ngah and Hanafiah, 2008). 'Coagulation and flocculation' is one such physicochemical process that has been used in the treatment of different types of wastewaters since it is highly efficient and a cost effective process for removal of fine particulate matters and other pollutants (Bartby, 1981; Lee et al., 2012). Common chemical coagulants such as inorganic salts of iron and aluminium tend to produce high sludge volume and residual metal ions in the treated water resulting in secondary pollution, increasing handling and disposal costs (Bartby, 1981; Lee et al., 2014). In recent years, biopolymers such as chitosan, tannin, gums and cellulose have been studied for the removal of contaminants from wastewater (Beltrán Heredia and Sánchez Martín, 2009; Das et al., 2012; Freitas et al., 2015; Mishra and Bajpai, 2005; Mukherjee et al., 2014; Renault et al., 2009). Biopolymers tend to produce compact flocs and do not cause any secondary pollution in the treated water. Also, they are

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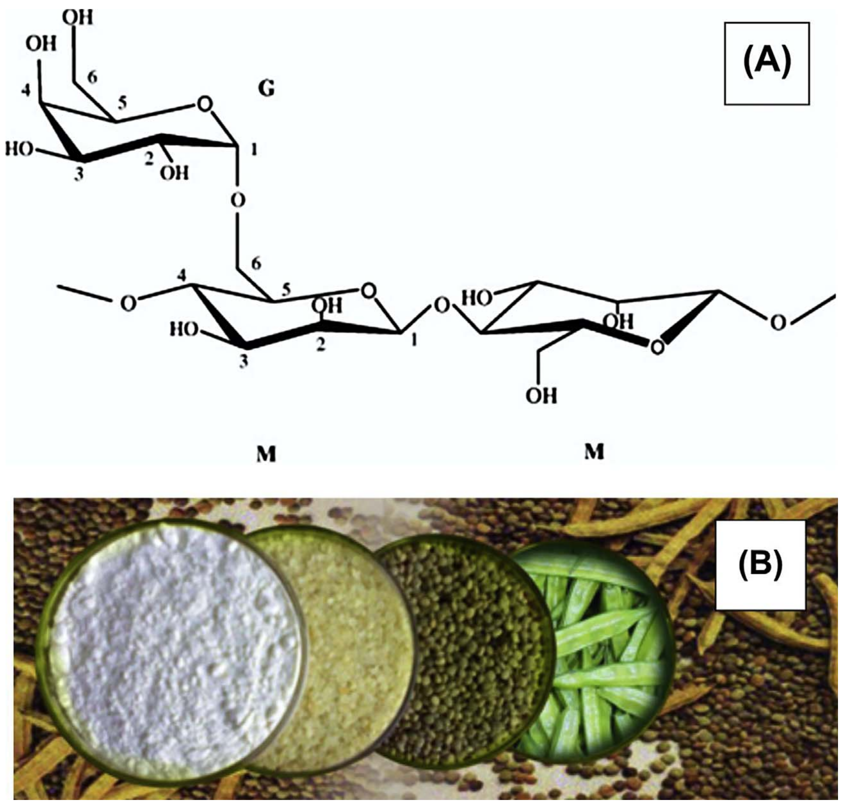

Fig. 1. (A) Chemical structure of guar gum showing the position of Galactose (G) and Mannose (M) in the guar gum polymer chain (Ding et al., 2008); Fig. 2.1. (B) Guar gum seed and powder.

Table 1
Experimental design summary.

Variables	Actual values for the coded values				
	-α	−1	0	+1	+α
Dose of flocculants, mgL-1 (**A**)	0.41	0.75	1.25	1.75	2.09
pH (**B**)	2.32	3	4	5	5.68
Initial Pb concentration, mgL^{-1}, (**C**)	1.59	5	10	15	18.41

Table 2
Actual design of the experiment.

Run	Dose (mgL^{-1})	pH	Initial Concentration of Pb (mgL^{-1})
1	1.25	4	18.4
2	0.41	4	10
3	0.75	3	15
4	1.25	4	10
5	1.75	5	15
6	0.75	5	5
7	1.25	4	10
8	1.75	3	15
9	0.75	3	5
10	2.1	4	10
11	1.25	5.6	10
12	1.25	2.3	10
13	1.25	4	10
14	1.25	4	1.6
15	1.25	4	10
16	1.25	4	10
17	1.75	3	5
18	0.75	5	15
19	1.75	5	5
20	1.25	4	10

inexpensive and easily available (Bartby, 1981; Mukherjee et al., 2014; Oladoja, 2015).

Guar Gum is a biopolymer extracted from the seed of leguminous shrub Cyamopsis tetragonoloba, commonly known as guaran. The plant is widely grown in the Indian subcontinent, USA, Australia, and Africa. It can grow well in sandy soil with little rain and lots of sunshine. It is an annual plant and is tremendously draught resistant (Altrafine Gums, 2014). The guar plant grows to a height of 0.609 m–2.74 m and resembles soybean plant in appearance. The plant's flower buds start out white and change to a light pink as the flower opens. The flowers turn deep purple and are followed by fleshy seed pods which ripen and harvested in summer. The seed pods grow in bunches giving guar the common name cluster-bean and each pod can have up to 5–6 round seeds. The biopolymer is extracted from the seeds (Mudgil et al., 2014) and is a polysaccharide composed of mannose backbone and galactose side branch on every alternate mannose units (Altrafine Gums, 2014). Recent studies have shown that it can be applied for the treatment of drinking water, industrial effluent and removal of persistent organic pollutants (Kee et al., 2015; Mukherjee et al., 2013; Sen Gupta and Ako, 2005). The objective of this work was to evaluate the feasibility of using guar gum to remove Pb^{2+} from wastewater for the very first time. The efficiency of guar gum in the removal of Pb^{2+} has been compared to a conventional inorganic coagulant potassium alum and attempt has been made to understand the mechanism of Pb^{2+} removal through FTIR and zeta potential studies.

2. Material and methods

2.1. Simulated wastewater and chemicals

Synthetic wastewater was prepared by combining lead nitrate ($Pb(NO_3)_2$) solution and kaolinite suspension. 250 mg L^{-1} stock solution of $Pb(NO_3)_2$ was prepared. The wastewater was prepared by mixing 0.1 g kaolinite into 1 L distilled water and was allowed to stand for 30 min.