Removal of Heavy Metals from Waste Water Using Black Teawaste

Abstract  Removal of heavy metals (Cobalt, Cadmium, and Zinc) from waste water was possible using black teawaste. Adsorption was observed for the three metals at 180 min. Under our experimental conditions, pH plays an important role in the adsorption process, particularly on the adsorption capacity of teawaste for the heavy metals under study. The pH level allowing for an optimum rate of adsorption was found to be 6 for Co, Cd, and Zn. We demonstrate that black teawaste has a relatively high adsorption capacity for these heavy metals; the quantities adsorbed per a half gram of black teawaste at equilibrium ($q_e$) are 15.39 mg/g for Co, 13.77 mg/g for Cd, and 12.24 mg/g for Zn. It was found that the percentage of removed metal ions is inversely proportional to initial metal ions concentration, but correlates with teawaste adsorbent dosage. The adsorption of heavy metals on black teawaste is described by an isotherm of type I and is fully verified by the Freundlich and Langmuir isotherms. The kinetics of the Cobalt, Cadmium, and Zinc adsorption on the teawaste were found to follow a pseudo first-order rate equation. This method has the advantage of being applicable in developing countries due to the low cost and availability of teawaste.

Keywords  Teawaste · Heavy metal removal · Cobalt · Cadmium · Zinc · Isotherms · Kinetics
1 Introduction

The elimination of metal ions from aqueous solutions by biosorption plays an important role in water pollution control and has become a matter of concern over the last few decades. Toxic heavy metal contamination of industrial wastewater is an important environmental problem due to its non-biodegradability and persistence, leading to its accumulation in the environment, including the food chain, and may thus pose a significant danger to human health [1,2]. Many industries, such as the automotive, metal-finishing, electroplating, tannery, steel and textile industries as well as the manufacture of electrical equipment, paints, alloys, batteries, pesticides or preservatives, release various concentrations of heavy metals such as lead, cadmium, zinc, cobalt, nickel, copper, etc. The commonly used procedures for removing metal ions from effluents include chemical precipitation, lime coagulation, ion exchange, and solvent extraction [3]. These techniques, apart from being economically expensive, have disadvantages such as incomplete metal removal as well as high reagent and energy requirements. The widespread industrial use of low-cost adsorbents for wastewater treatment is thus highly desirable at present, due to their local availability, technical feasibility, engineering applicability and cost effectiveness [4]. Consequently, several serious efforts have been undertaken to find adequate efficient and low-cost materials. For instance, most agricultural waste or by-products are considered to be low-value products. Different types of biomass have been investigated for biosorption of Cr, Co, Ni, Zn, Pb and Cd. These include wool, rice, straw, coconut husks, peat moss, exhausted coffee [5], walnut skin, coconut fiber [6], cow bone charcoal [7], defatted rice bran, rice hulls, soybean hulls and cotton seed hulls [8,9], wheat bran, hardwood sawdust, pea pod, cotton and mustard seed cakes [4,10] and others.

Tea is one of the world’s most popular beverages. Indeed, about 3.5 million tons of tea are consumed worldwide annually. A big volume of spent tealeaf or tealeaf residue is thus released into the environment through daily tea drinking, including instant tea ready-to-drink teas.

In recent years, there has been an interest in the use of black tea leaves as a low cost adsorbent because of their high capacity for heavy metals removal. Some of the investigations have been mainly focused on the conformational aspects of their removal or sorption capacities. Others, however, have been interested in kinetics, an important physicochemical factor in evaluating the basic qualities of an adsorbent as well as the application of the adsorption process. Hossain et al. [11] carried out kinetic investigations to evaluate the applicability of used black tea leaves to the removal of chromium(VI) from aqueous solutions. The effects of various kinetic parameters were investigated using a batch process. They found that adsorption of Cr(VI) on tea waste occurs rapidly in the first day, and is followed by a slow process that requires more than 10 days to reach its equilibrium. The rate of adsorption was found to be affected by the processing conditions such as the initial Cr(VI) concentration, solution pH, temperature and foreign ions.

Amarasinghe and Williams [12] conducted batch experiments to determine the factors affecting kinetics and adsorption of copper and lead ions onto tea waste from aqueous solutions. Fixed bed column experiments were performed to study practical applicability, leading to breakthrough curves being obtained. Tea waste is capable of binding significant amounts of Pb and Cu from aqueous solutions. The adsorption capacity was highest at solution pH range 5–6. The adsorbent-to-solution ratio and the metal ion concentration in the solution affect the degree of metal ion removal. Pb showed higher affinity and adsorption rates compared to Cu under all experimental conditions.

Yoshita et al. [13] prepared an adsorbent using spent tea leaves and used it to remove lead (Pb) from the solution. The Pb removal by the spent tea leaf adsorbent depend on its pretreatment, adsorption contact time and adsorbent dosage.

Antonio and Roberto [14] showed that removal efficiencies of up to 98–99% can be achieved when using spent tea leaves as lead adsorbent. The results were only marginally affected by the type of tea waste used. At low-load loading, the adsorption equilibrium was well described by the Langmuir equation, with a maximum adsorption capacity of 83–130 mg/g and an equilibrium constant ranging from 0.112–0.245 L/mg. A comparison with other adsorbents provided the following order for lead removal efficiency: Black tea, coffee grounds > green tea > Fuller’s earth > activated carbon.

The aim of this research is to develop inexpensive and effective heavy metals adsorbents from abundant sources of natural waste, such as tea waste, to replace existing commercial materials. However, there have been few studies on the utilisation of black tea waste. The present study aims at using black tea waste as adsorbent to remove cobalt, cadmium and zinc from aqueous solutions. To our knowledge, no such study exists for cobalt adsorption on black teawaste. Moreover, there are few studies on the lack of adsorption kinetics of zinc on black teawaste. In our work, the impact of solution pH, initial metal ions concentration, shaking time and solid/liquid ratio on the removal of metal ions by teawaste biosorbent were studied.