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Adsorption of Lead on Cucumber Peel

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ABSTRACT

The competency of cucumber peel (CP) was explored for adsorption of lead. Optimum adsorption occurred at pH 5.0 and at incubation temperature of 30 °C. The process of adsorption was quite fast to be completed within a time frame of 60 min obeying pseudo second order rate kinetics. 1.0 g sorbent was capable enough to adsorb 133.60 mg lead (q_{max}) with Langmuir isotherm model categorically illustrating the adsorption process. The magnitude of hindrance exerted by cadmium in binary system as a consequence of co-ion effect was found to be rather insignificant. Functional group modification study confirmed principal role of carboxyl group in metal binding. The biomass was characterized by different instrumental analyses like TGA, SEM, EDAX, XRD, FTIR and zeta potential measurement which additionally authenticated the sorption phenomenon. Post adsorption elution of the loaded metal was successfully executed using HCl as eluant.

1. Introduction

Water pollution, a severe environmental concern of the present world is escalating at an alarming rate despite all mitigating measures due to ever-increasing industrialization. Release of untreated industrial effluents contaminated with organic and inorganic pollutants including heavy metals enhance the problem to the utmost extent. Lead being an indispensible element is widely used in various industrial applications though the treatment strategy of lead contaminated effluents depends on the type of industries concerned. Reddy et al. (2010) emphasized that international authorities like United States Environmental Protection Agency (USEPA) and United States Agency for Toxic Substances and Disease Registry (USATSDR) have already acknowledged it as one of the hazardous and non biodegradable heavy metals posing danger to human and other life forms. A well documented fact highlighted by Chen et al. (2016), that vital organs and systems are damaged and normal metabolic functioning of the body are disrupted upon lead poisoning. In human beings lead is known to cause neural toxicity, depression, encephalopathy, mood changes, dizziness, forgetfulness besides attacking kidney, liver and brain as explained by Ren et al. (2015). The industrial processes that contribute to anthropogenic lead pollution are metal plating, battery manufacturing units, printing, lead mining and smelting operations along with ceramics and glass goods productions stated by Liu et al. (2016). In order to mitigate lead poisoning World Health Organization (WHO) has restricted its maximum concentration in drinking water to 0.01 mg L^{-1}, reported by Sarada et al. (2014) and Environmental Regulatory Authority of India has directed to lower the concentration of lead to 1.0 mg L^{-1} in effluents before disposal, informed by Bairagi et al. (2011). Kong et al. (2014) mentioned that some chemical treatment procedures like reverse osmosis, coagulation, chemical precipitation, electro dialysis, ultra filtration are employed with a view to clean wastewaters. However these techniques are not at all satisfactory either in the standard of performance or at the cost of execution. Activated carbon seems to be the only option but it is also associated with high cost and without any provision for regeneration. These constraints have made the researchers to adopt a greener, cleaner and inexpensive technology; the biosorption. Biosorption as defined by Das et al. (2007) exploits the innate binding ability of different biomaterials for organic and inorganic contaminants from their respective solution. The process is designated as 'green and clean' as it promises minimized sludge generation by repeated use of the same sorbent with a provision for sorbate recovery. What's more, it is a 'cost effective' method utilizing local and commonly available biological sorbents like fruit and vegetable peels, agricultural wastes and other plant materials in decontamination procedure. Literature review shows extensive use of different biological adsorbents viz. utilization of pongamia oil

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cake by Shanmugaprakash and Sivakumar (2015); employment of chemically treated tomato waste by Yargic et al. (2015); experimentation of pomegranate peel by Ben-Ali et al. (2017): exploration of lentil husk by Basu et al. (2015): application of *Dicerocaryum eriocarpum* plant mucilage by Jones et al. (2016) to adsorb heavy metals from contaminated water. In analogy with the incessant search for cheaper, feasible and probable sorbent the efficacy of cucumber peel (CP) has been explored in this research work to assess its lead adsorption potential.

Cucumber is a very popular fruit that is consumed in all seasons. Although being eaten as fruit it is used in various other food items. Cucumber peel (CP) is generated in massive quantities everyday and is disposed as garbage creating another source of pollution. CP is rich in biopolymers like cellulose, hemicellulose and lignin. These biopolymers possess various functional groups (carboxyl, hydroxyl, amino, phosphate, carbonyl etc.) that can be the binding sites for heavy metals. Our investigation aims at detailed characterization of CP and comprehensive study of the adsorption procedure to evaluate the usefulness of this sorbent.

2. Materials and methods

2.1. Chemical reagents

All the chemical reagents used in this research work were of analytical reagent (AR) grade from E. Merck, Darmstadt, Germany.

2.2. Biosorbents

The biomaterials employed comprised of orange peel, cucumber peel, mango peel, pea peel, groundnut shell and sweet lemon peel which were procured from adjacent areas. Thus, these materials were washed thoroughly first with tap water followed by deionized water to get rid of dust and other adhering particles. The washed sorbents were oven dried at 60–70 °C until a steady weight was attained. The biosorbents were grounded into fine particles to pass through 36-mesh screen and stored in desiccated condition for experimental purpose.

2.3. Analysis of components of CP

Cellulose, hemicellulose and lignin form essential ingredients of plant biomass apart from extractives, moisture and ash content. In this study a thorough analysis of different structural components of CP was conducted following the procedures of Li et al. (2004). Moisture and ash contents were analyzed according to Zainuddin et al. (2014).

2.3.1. Moisture content

2.0 g CP was oven dried at 80 °C in porcelain crucible. Initial and final weights of the sample containing crucibles were measured and the moisture content was calculated by Equation (1).

$$\frac{(Initial\ weight\ of\ filled\ crucible) - (Final\ weight\ of\ filled\ crucible)}{(Initial\ weight\ of\ filled\ crucible) - (Initial\ weight\ of\ empty\ crucible)} \times 100\% \quad (1)$$

2.3.2. Ash content

The amount of ash present was determined by incinerating 3.0 g CP in washed porcelain crucible in muffle furnace at 700 °C for 8 h. The cooled ash was weighed and the ash content was calculated by Equation (2).

$$\frac{Weight\ of\ ash}{Weight\ ofbiomass} = \%\ of\ ash \quad (2)$$

2.3.3. Extractives analysis

Dried and powdered CP (G_0, g) was contacted with a mixture of benzene and ethanol (2:1) for 3 h at 30 °C. The residue after being oven dried at 105–110 °C (till constant weight) was cooled to room temperature and weighed again (G_1, g). Weight of extractives was calculated by Equation (3).

$$W_1(wt\%) = \frac{G_0 - G_1}{G_0} \times 100\% \quad (3)$$

2.3.4. Hemicellulose analysis

The residue G_1 after extractive analysis was developed with 150 mL NaOH solution (20 g L^{-1}). The mixture was refluxed for 3.5 h. The washed residue was dried to constant weight followed by cooling to room temperature and weighed again (G_2, g). Weight of hemicellulose was calculated by Equation (4).

$$W_2(wt\%) = \frac{G_1 - G_2}{G_0} \times 100\% \quad (4)$$

2.3.5. Lignin analysis

Following extractive analysis 1.0 g residue was oven dried (till constant weight), cooled and weighed (G_3, g). 30 mL H_2SO_4 was added and the mixture was kept at 14 °C for 24 h followed by dilution with 300 mL distilled water and reflux for 1 h. After filtration the residue was washed thoroughly till no sulfate ion was present in the filtrate (detected by 10% barium chloride). Finally the oven dried residue was cooled and weighed (G_4, g). Weight of lignin was calculated by Equation (5).

$$W_3(wt\%) = \frac{G_4\ (1 - W_1)}{G_3} \times 100\% \quad (5)$$

2.3.6. Cellulose analysis

Weight of cellulose was calculated by Equation (6).

$$W_4(wt\%) = 100 - (W_1 + W_2 + W_3 + Ash) \quad (6)$$

2.4. Thermo gravimetric analysis

A plant material contains several components which get volatilized by progressive heating of the biomass in thermo gravimetric analyzer. In this analysis weight loss of the biomass served as an indicator of degradation of its components as a function of temperature. Thermo gravimetric analysis (TGA) of CP was conducted in Thermo gravimetric analyzer (Pyris Diamond TG/DTA, Perkin Elmer, Singapore) in nitrogen atmosphere (150 mL min^{-1}) in platinum crucibles. The heating rate of the biomass was 20 °C min^{-1} with temperature ranging from 30 to 1000 °C.

2.5. Zeta potential measurement

Zeta potential measurement was done to inspect the variation of surface charge of CP corresponding to changing pH values. The instrument used for the purpose was Malvern Zetasizer (Model No. Zen 3690 Zetasizer Nano ZS 90). The experiment was executed as per protocol of Li and Bai (2005) which suggested suspending of 0.1 g powdered biomass in 100 mL deionised water. The resulting