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ORIGINAL ARTICLE

Nitrilotriacetic acid functionalized *Adansonia digitata* biosorbent: Preparation, characterization and sorption of Pb (II) and Cu (II) pollutants from aqueous solution

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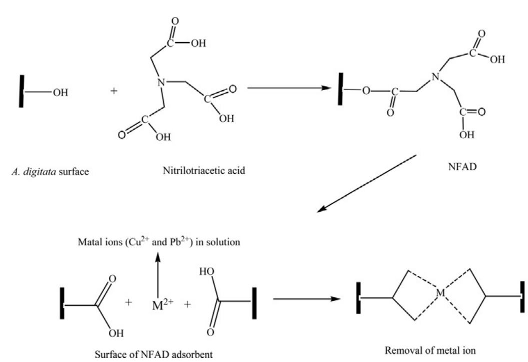
GRAPHICAL ABSTRACT



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ABSTRACT

Nitrilotriacetic acid functionalized *Adansonia digitata* (NFAD) biosorbent has been synthesized using a simple and novel method. NFAD was characterized by X-ray Diffraction analysis technique (XRD), Scanning Electron Microscopy (SEM), Brunauer-Emmett-Teller (BET) surface

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area analyzer, Fourier Transform Infrared spectrometer (FTIR), particle size dispersion, zeta potential, elemental analysis (CHNS/O analyzer), thermogravimetric analysis (TGA), differential thermal analysis (DTA), derivative thermogravimetric analysis (DTG) and energy dispersive spectroscopy (EDS). The ability of NFAD as biosorbent was evaluated for the removal of Pb (II) and Cu (II) ions from aqueous solutions. The particle distribution of NFAD was found to be monomodal while SEM revealed the surface to be heterogeneous. The adsorption capacity of NFAD toward Pb (II) ions was 54.417 mg/g while that of Cu (II) ions was found to be 9.349 mg/g. The adsorption of these metals was found to be monolayer, second-order-kinetic, and controlled by both intra-particle diffusion and liquid film diffusion. The results of this study were compared better than some reported biosorbents in the literature. The current study has revealed NFAD to be an effective biosorbent for the removal of Pb (II) and Cu (II) from aqueous solution.

Introduction

Water is essential for life and it is desired to be safe, potable, appealing to all life on earth and should be free of pollutants that are harmful to human, animal, and the environment. In spite of the vast majority of water bodies available in the world, clean water is not easily accessible or readily available in most parts of the globe most especially in the developing nations.

Potentially toxic metals such as copper (Cu) and lead (Pb) have been identified as pollutants found in water. Potentially toxic metal contamination in aquatic environment has attracted global attention due to its environmental and health risks, toxicity, abundance, and persistence [1,2]. Cu and Pb are capable of reaching aquatic environment through anthropogenic processes like fumes from paint, scrap from old batteries, cable sheathing, ceramic ware, and renovations resulting in dust [3]. The presence of potentially toxic metals has been reported in rivers, streams, ground water, and surface water as a result of global industrialization, rapid population growth, agricultural production, and intensive domestic activities [4]. The treatment of these generated domestic and industrial wastes has been of concern as most of these wastes are not properly treated before being discharged or discarded into the environment. This action has always resulted in pollution of water bodies present in such environment and ultimately leading to increase in the level of potentially toxic metals in the environment as these metals can bioaccumulate over a period of time. These potentially toxic metals are toxic to human, animal, and the environment most especially when humans and animals drink from such polluted water sources. Cu and Pb are harmful as they can accumulate in living organisms; they are non-biodegradable and are capable of causing various diseases and disorders.

Several approaches have been employed for the removal of potentially toxic metal ions from wastewater. Some of these include chemical precipitation, ion-exchange, electrodialysis, flocculation, solvent extraction, coagulation, photocatalysis, membrane separation, and adsorption [5–9]. Of these, adsorption method is one of the most popular and effective processes for removing toxic heavy metal from polluted water due to its flexibility in design and operation [5]. Research attentions have been focused on the search for environmentally friendly low-cost biomass adsorbents that have good metal binding capacities. Some biomasses have been identified in this regards but the adsorption capacity and selectivity of some of them need to be improved on [2,5]. So, it is important to develop cheap and eco-friendly adsorbents with high metal removal, excellent selectivity, and fast process kinetics.

Several methods, such as nitration, acid and alkali modification, oxidation, and chemical grafting, have been used to enhance the adsorption performance of some biomass [10,11] but the results have shown that a number of them are either expensive or with low selectivity and sometimes may not be suitable for industrial wastewater which may be highly concentrated with these potentially toxic metals. It is important to develop low-cost adsorbents that will be efficient with sufficient capacity in treating this highly polluted industrial wastewater before they are discharged into the environment. Previously reported works have shown that biomass has the capacity of removing potentially toxic metals from aqueous solution but mostly at a capacity which may require enhancement [11]. Pehlivan et al. [12] reported a capacity of 4.64 mg/g for Cu (II) ions using barley straw while Alhakawati and Banks [13] reported 2.35 mg/g for sea weed. Several other biomasses such as orange peel [14], rice husk [15], natural bentonite [16], *Eichornia Crassipes* [17] and coconut shell [18] had also been used for the removal of Pb (II) and Cu (II) ions from aqueous solution with indications that these biomasses would have performed better if modified.

Nitrilotriacetic acid is an aminopolycarboxylic acid with high propensity of being able to use its carboxyl functional group in chelating metals. It also has an amine group on the molecular chain which may also exhibit strong adsorption ability for potentially toxic metals. With its pH range and functional groups, nitrilotriacetic compound should be able to bind with potentially toxic metal ions (such as Cu (II) and Pb (II)) through complexation or electrostatic interaction. In adsorption technology, surface functionalization has been proven to be effective [19]. In this context, the use of nitrilotriacetic acid in surface functionalization of a cheap underutilized biomass such as *Adansonia digitata* may be an economic viable means of tackling this need. *A. digitata* is an underutilized plant in Nigeria which belongs to the Bombacaceae plant family. Presently, the seed has no specific use in Nigeria and most times, it is discarded as waste. The seed is underutilized and chemical evaluation of the seed has shown it to be rich in some essential amino