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The adsorption kinetics and modeling for heavy metals removal from wastewater by *Moringa* pods

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ABSTRACT

The investigation of the effectiveness of the removal of copper, nickel, chromium and zinc ions from synthetic waste water by using *Moringa aptera* Gaertn (MAG) was studied. The effect of biosorption experimental parameters such as initial metal concentration, contact time, temperature and adsorbent dose has been presented and discussed in details. The equilibrium data for biosorption were analysed by using Langmuir, Freundlich, Temkin and Dubinin–Radushkevich isotherm models to define the best correlation for each metal.

Among the four isotherm models, both Freundlich and Temkin models were fitted with the equilibrium isotherm for copper, while Temkin and Dubinin–Radushkevich models best correlated for nickel and Langmuir isotherm model best describe the experimental data for chromium. The adsorption capacity for each studied heavy metals is reported as follows: copper q_e = 6.07 mg Cu/g MAG, nickel q_e = 5.53 mg Ni/g MAG and chromium q_e = 5.497 mg Cr/g MAG with a removal percentage of 90%, 68% and 91%, respectively for each ion at 1 g dose of biosorbent. Results also show that MAG pods are not a good biosorbent for the removal of zinc from wastewater. Kinetics results were best described by pseudo-second order model for all metals.

Introduction

Heavy metals have hazardous impact to ecosystem including human, animals and plant health. Therefore, the Word Heath Organization (WHO) and Environmental Protection Agency (EPA) have regulated the maximum acceptable discharge level into the environments and thus controlling the water pollution level. According to U.S. Environmental Protection Agency (EPA), Agency for Toxic Substances and Disease Registry (ATSDR), and World Health Organization (WHO), the max acceptable concentrations recommended for zinc, copper, chromium and nickel in drinking water is 3.00, 2.00, 0.05 and 0.02 mg/L, respectively [1].

Most of heavy metals are assimilated, stored and even accumulated into the human body causing chronic problems. Hence, it is necessary to remove these heavy metals from industrial influents before discharging waste aqueous solution into environment [2–4].

Several chemical and physical technologies have been used and developed to remove high concentration of toxic heavy metals from waste water including: precipitations, solvent extraction, ion-exchanger, reverse osmosis [5,6], oxidation/reduction, sedimentation, filtration, electrochemical techniques, and cation surfactant, etc. [7]. However, these traditional methods require further research and development due to their high operational cost, low removal efficiency at low concentration, and toxic sludge generation which requires additional treatment. This has focused researchers to find alternative economical methods for wastewater treatment.

Biosorption represents the ability of biological materials in removal of heavy metals from aqueous effluents. Biosorbents have high efficiency, selectivity and its natural affinity to metal ions. The mechanism of removal can be described as ion exchange, electrostatic force and precipitation. In addition, biosorption is widely used due to their natural availability in environment and low costs.

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First studies on *Moringa oleifera* (MO) were done in 1981 by Jahn after observing Sudanese women that have used the seeds as a coagulant in purifying the turbidity of Nile water. Other studies done by Vieira et al. [8] showed that MO seeds used as a natural adsorbent have a strong removal efficiency reaching up to 98% for both color and turbidity. While Arnoldsson et al. [9] mentioned the negligible effect of MO seeds as a coagulant on pH, alkalinity or conductivity of water.

MO seeds have not only been studied for their coagulating properties but also for their ability to remove heavy metals from aqueous solutions. A study by Nand et al. [10] showed that MO was capable on adsorbing heavy metals more than other seed types. The percentage of removal was 90% for copper, 80% for lead, 60% for cadmium and 50% for zinc and chromium.

Kalavathy and Miranda [11] mentioned the potential of activated carbon *Moringa oleifera* (ACMO) for the removal of copper, nickel and zinc from synthetic wastewater under various conditions. Examples of these conditions include contact time, adsorbent dose, concentration, temperature, and solution pH.

Bhatti et al. [12] studied the use of pure and chemically pretreated biomass of MO in the removal of zinc ions from aqueous solution. Both Langmuir and Freundlich isotherm model fitted and verified the data. In addition, earlier studies showed that MO seeds powder is effective in heavy metals remediation of water [13].

Interest in biosorbent significantly increased within scientific communities. Several studies by Reddy et al. [14–16] have been published in several journals revealed that the economic potential of MO bark and chemically modified MO leaves for the removal of toxic heavy metals ions from aqueous solutions compared of other biosorbent. The experimental adsorption data were analysed using Langmuir, Freundlich, Temkin and Dubinin–Radushkevich isotherm models. The results showed that it follows a pseudo-second order behavior.

Santana [17] modified the increased of MO seeds powder dosage to reduce the turbidity, total dissolved solid (TDS), total solid (TS), hardness, acidity, most probable number (MPN) and statistical process control (SPC) in ground water. On the other hand, the increase of adsorbent dosage for arsenic pentoxide (V) has no influence on adsorption percentage and the maximum recorded removal percentage reached 70.7% [18].

Sharma et al. [19] studied batch experiments for cadmium. The results showed that the removal of toxic metals by using MO seeds could be considered as an economic and an environmental safe method for wastewater treatment. Furthermore, MO pods have been also used for removal of heavy metals. However, the result showed that a MO pod is not very good biosorbent for the removal of lead from wastewater [20].

The objective of this study is to test the effectiveness of *Moringa aptera* Gaertn (MAG) in the removal of heavy metals. Extensive study of heavy metal removal includes:

- Study of *Moringa aptera* Gaertn as a potential adsorbent for adsorption of heavy metals, and determine adsorption isotherm and kinetic model.
- Optimization of the conditions for maximum sorption by studying the effect of process parameters such as initial concentration, temperature, adsorbent dose and contact time on the removal of copper, nickel, chromium and zinc from aqueous solution by *Moringa aptera* Gaertn.

Fig. 1. *Moringa* species. Distribution in Jordan.
https://www.google.com/maps/d/edit?mid=zMv-kH1cOkwE.kDhxdzTKE_cw