Engineering and Technology Journal *Vol. 37, Part C, No. 1, 2019*

DOI: http://dx.doi.org/10.30684/etj.37.1C.22

Fourth International Scientific Conference on Environment and Sustainable Development (4th ISCESD), Egypt, Cairo, 24-28 November 2018

Evaluation Biosorption and Recovery of Zn, Cr And Ni Ions From Industrial Wastewater Using Beads of Banana Peel Powder Constrained by Calcium Alginate

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Received on: 01/08/2018
Accepted on: 10/01/2019
Published online: 25/04/2019

Abstract- *Plant wastes have been successfully applied as biosorbent materials of several heavy metal ions from industrial wastewater due to the obvious capability of removing significant quantities of heavy metal ions. In the current work, banana peel powder was constrained by calcium alginate for polymerization and bead formation and subjected to both biosorption and recovery processes of Zn, Cr and Ni ions from untreated wastewater, collected from general state electrical manufacturing company in Baghdad-Iraq, using designed laboratory treatment unite. It has been found that the capacity of immobilized banana peel was significantly higher in bioremoving Zn, Cr and Ni ions than that of calcium alginate where mean biosorption capacities of Zn, Cr and Ni ions was 74.0 ± 2.3 mg/l, 83.0 ± 0.0 mg/l and 71.0 ± 1.8 mg/l respectively while in case of calcium alginate, these values were 25.0 ± 2.2 mg/l for Zn 34.0 ± 1.3 mg/l for Cr and 19.0 ± 0.9 mg/l for Ni. This study has found that biosorption capacities of heavy metal ions by immobilized banana beads, used in laboratory treatment unite, from industrial wastewater was much efficient where this lab designed unite had shown significant capacity of such beads in bioremoving all examined heavy metal ions by giving higher biosorption capacities which were 86.6 % in case of Zn ions and 100% for both Cr and Ni ions. In the recovery of these heavy metal ions from biosorbent immobilized banana beads, it was found that the percentages of recovered metal ions, from these beads used in laboratory unite, were very high ranging from 88.0 % in case of Cr ions to 90.5% for Zn ions while this recovery percentage was 88.7% for Ni ions.*

Keywords- *Biosorption, Recovery, Banana peel, Immobilized beans, Heavy metal ions, Industrial wastewater*

How to cite this article: S.M. Shartooh, S.A.K. Al-Hiyaly, “Evaluation biosorption and Recovery of Zn, Cr and Ni ions from Industrial Wastewater Using Beads of Banana Peel Powder Constrained by Calcium Alginate,” *Engineering and Technology Journal*, Vol. 37, Part C, No. 1, pp. 139-144, 2019.

1. Introduction

Water with heavy metals pollution has expected significant consideration worldwide containing identifying, classifying, controlling, evaluating their environmental impacts, treating their effects and monitoring and examining for scientific tools to reduce and prevent any possible influences may arise [1]. However, various techniques were used towards removing heavy metals from polluted water [2] such as ion-exchange, chemical precipitation, electro dialysis, reverse osmosis (RO), membrane separations [3] and recently by using geopolymer [4]. All these techniques are rather expensive and is not effective enough to allow the recovery of very dilute heavy metals existing in the effluent, and are not appropriate for small-scale industries [5]. Biosorption has been suggested as one of the greatest promising biological techniques for the removal of toxic metals from wastewater [6,7]. However, such a process has several advantages associated with those predictable techniques [8] such as less expensive, high efficiency, metal selective, no sludge generation and metal recovery.

The biosorption methods contains a solid phase (sorbent or sorbent; usually a biological material) and a liquid phase (solvent- normally water) containing a dissolved species to be sorbed (sorbate, a metal ion) in the treatment [9]. The sorbents can be categorized into microbial biomass for example bacteria, fungi, marine algae [10, 11] and biological materials or wastes such as; soya bean hulls, walnut hulls, cotton seed hulls, rice husk, crop milling waste, orange peels; certain grass species and corncob [12-15]. These sorbents are containing mostly of polysaccharides, proteins and lipids, functional groups that can bind metal ions such as carboxylate, hydroxyl, sulphate, phosphate and amino groups [16].

Plant waste materials which are presented in large quantities from many processes and almost costless, may be successful alternative sorbent material to be used as effective adsorbents [17] such as fruit peels, tree bark, peanut skin and growing plants (tobacco and tomato root tissues) were used to remove different metals ions from polluted water [18].

Several studies have shown that banana peels could quickly remove heavy metals from river water and is at least as effective, and in some cases even better than existing methods [19]. Evidently, banana peels are rich in negative charged molecules, so they attract the heavy and positively charged metal pollutants in water, and they are quite effective, also, for every treatment with the peel powder, around 65 percent of the water was decontaminated [20].

The selection of a carrier for immobilization is determined by the type of biological material and procedures of immobilization. Porous materials are used most frequently for their ability to form a free contact of the substrate with an immobilized biocatalyst, including carrageenan, polyacrylamide gel, and calcium or sodium alginate [21]. Additional advantage resulting from the application of such technical solutions is cost-effectiveness of the reaction.

This study was designed to examine biosorption capacities of Zn, Cr and Ni ions from industrial wastewater of general state electrical manufacturing company by using immobilized biosorbent formed from banana peel powder and calcium alginate and testifying the process of recovery of metal ions from these biosorbent materials using two different recovery chemical agents which are HCl 0.1 M & EDTA 0.1 M.

2. Materials and Methods

Banana peels were collected from the local market and washed thoroughly using de-ionized distal water, air-dried at lab conditions and powdered and sieved by 0.075mm-4mm stainless steel sieves. Immobilization technique was used to immobilize banana peels powder into an alginate solution to form a bead. The powdered biomass of banana peels was immobilized by entrapment in polymer matric of Na-alginate, by solving 1 g of Na-alginate in 100 ml of distilled water (1% w/v), mixed thoroughly by stirring on a magnetic stirrer. After that banana peel powder (biomass) were added to the sodium alginate solution at a specific weight.

The alginate biomass slurry was introduced into 0.1*M* of $CaCl_2$ (dissolving 5.549g of $CaCl_2$ in 500 ml of de-ionized distill water) for polymerization and bead formation using 5 ml syringe. The resultant beads were about 4 mm in diameter (Figure 1). The peel entrapped beads were cured in this solution for 1hr and then washed twice with 200 ml of de-ionized distill water and preserved in 5m*M* of $CaCl_2$ (dissolving 0.278g of $CaCl_2$ in 500 ml of de-ionized distill water) at 4°C for further use [22].

Figure 1: Free and immobilized beads

Industrial wastewater containing these three metal ions (Zn, Cr, Ni) was examined for biosorption capacities by using calcium alginate alone and the beads formed from banana peel powder constrained by calcium alginate. The laboratory unit for the biological treatment was designed depending on the continuous flow system technique by using a sterilized glass column containing the biomass beads which are formed from the powder of banana peels with Ca-alginate (Figure 2). Thus, the metal solution used for treatment passes through a filter membrane located in the bottom of the column by a peristaltic pump with a flow rate of 0.5 ml/min. And the system was incubated at 40°C. Then the resulted water was gathered from the top of the glass column (through a filter paper unit) for heavy metal concentration measurements by FAAS [23].

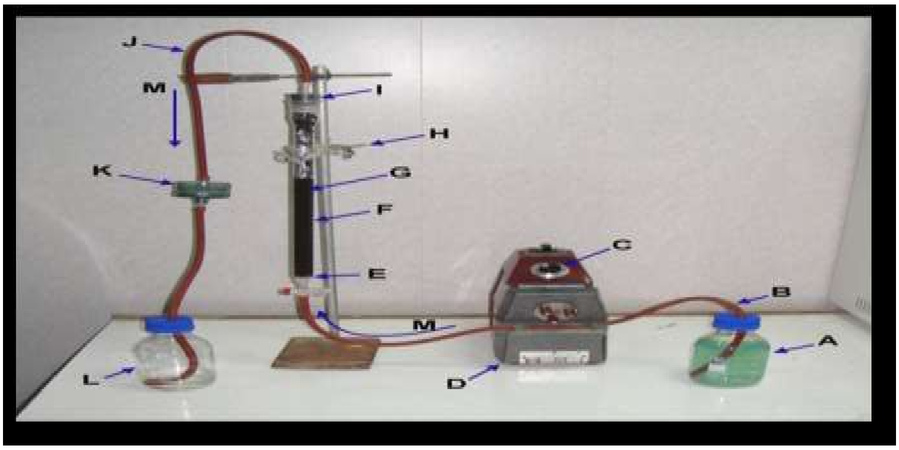

Figure 2: Laboratory treatment unit design

Where: A**.** Glass bottle containing the metal solution, B. Pipeline delivers, C. Flow rate regulator, D. Peristaltic pump, E. Filter, F. Glass column, G. Beads, H. Holder, I. Rubber plug, J. Pipeline, K. passes through the rubber plug, L. Collecting bottle (to the FAAS), M. Flow direction.

Industrial wastewater samples were collected from State Electrical Manufacturing Company – Baghdad and firstly examined for Cr, Ni and Zn content using Flameless Absorption Atomic Spectrophotometer [23]. Secondly, this wastewater was tested for biosorption capacity using formed banana peel powder beads. After biosorption process, these biosorbent banana peel powder beads were subjected for further process to recover these biosorbed heavy metal ions using EDTA and HCl solutions where precipitated biosorbent material was collected after biosorption process and placed into volumetric flasks. Twenty ml of 0.1 *M* EDTA or 0.1 *M* HCl was added to each flask. The mixture was then equilibrated for 1 hr. At 50°C before centrifuging at 2000 rpm for 4 min. The supernatant was passed through a 0.45µm membrane filter and metal content in the supernatant was tested again using FAAS [23].

3. Results and Discussion

Table 1 shows mean values of pH, electrical conductivity (E.C), Zn, Cr and Ni ions concentrations of industrial wastewater samples from State Electrical Manufacturing Company.

Table 1: Mean values ± Standard deviation of pH, electrical conductivity (E.C), Zn, Cr and Ni ions concentrations of examined industrial wastewater samples.

Variables	Mean value ± Standard deviation
pH	7.39 ± 0.181
Electric conductivity µs/cm	2.081 ± 0.141
Zn ions mg/l	522.675 ± 68.835
Cr ions mg/l	46.418 ± 1.933
Ni ions mg/l	9.505 ± 1.489

The mean pH value of these samples was 7.39 ± 0.181 while E.C means the value was 2.081 ± 0.141 µs/cm. Regarding heavy metal contents of these samples, it has found that the mean concentration of Zn, Cr and Ni was 522.675 ± 68.835 mg/l, 46.418 ± 1.933 mg/l and 9.505 ± 1.489 mg/l respectively.

In biosorption capacity test of both calcium alginate and beads formed from banana peel powder, it seems that the capacity of banana peels immobilized to calcium alginate had much higher biosorption capacity than that of calcium alginate for all examined heavy metal ions (Zn, Cr, and Ni) from industrial wastewater (Figure 3).

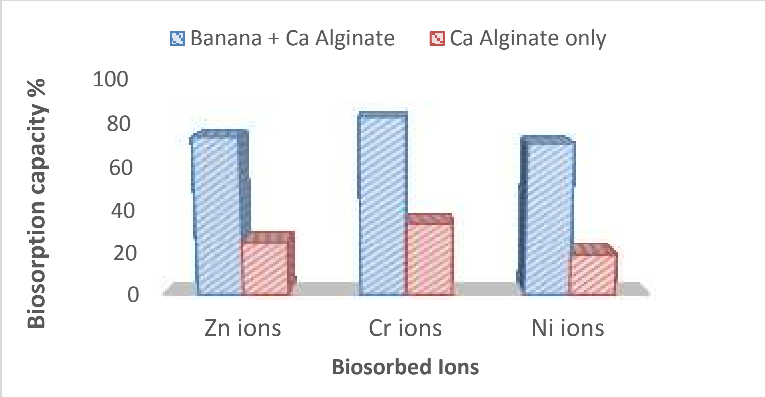

Figure 3: Mean Zn, Cr, and Ni ions biosorbed from industrial wastewater by banana peels constrained by calcium alginate and by only calcium alginate.

It seems clearly that the biosorption capacity of banana peel powder constrained by calcium alginate was significantly higher (P≥ 0.05) than that capacity of calcium alginate where mean biosorption capacities of Zn, Cr and Ni ions were 74.0 ± 2.3 mg/l, 83.0 ± 0.0 mg/l and 71.0 ± 1.8 mg/l respectively while in case of calcium alginate, these values were 25.0 ± 2.2 mg/l for Zn, 34.0 ± 1.3 mg/l for Cr and 19.0 ± 0.9 mg/l for Ni (Figure 4).

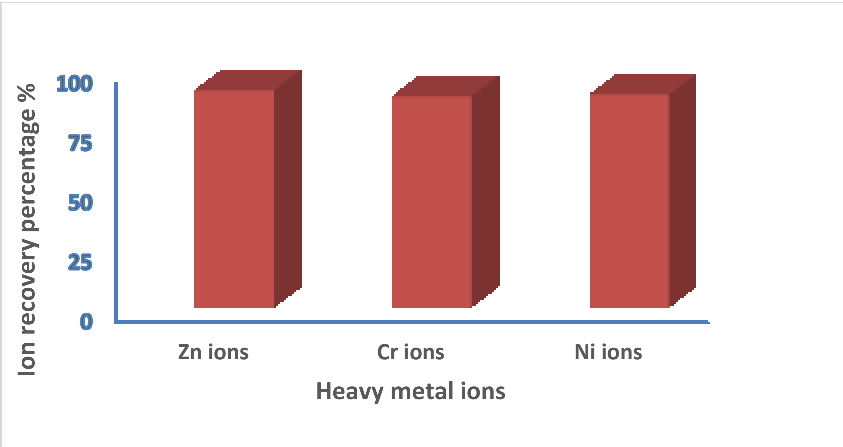

Figure 4: Percentage of recovered metal ions (%) by banana peels constrained by calcium alginate.

Alginate is a polysaccharide with a high affinity and binding capacity for metal ions [24]. Some alginates – based sorbents have been tested for metal uptake from aqueous solutions, but the most common was calcium alginate gel beads [25].

A previous study [26] has found that the calcium alginate beads exhibited a considerable capacity to uptake metal ions from a metal plating effluent and sorption kinetics quicker than a commercial ion-exchange resin.

In general, it is very obvious that the biosorption capacity of examined heavy metal ions from industrial wastewater with beads formed from banana peel powder constrained by calcium alginate was very effective in bioremoving such ions from industrial wastewater and this may be due to increase activity through active groups such as carboxyl and hydroxyl [27]. However, the results of this study show that the uptake levels of metal ions were higher than the levels obtained from another treatment unit system designed by similar work [28] which did not use the alginate beads in such treatment.

Many studies have shown the importance of the use of alginate beads technique in the continuous flow system [29] since this technique can treat large amounts of industrial wastewater and can treat even very little concentrations of heavy metals which can be approximately 10-50ppb [30].

The results of this study are backed by a previous study [31] which reported that the immobilizing technique by calcium alginate gives the best results in bioremoving of lead ions from aqueous solutions. Similar findings were reported by another study [32] on immobilized konkoli leaves for the removal of Pb' Cd and Zn ions in aqueous solution. Also, the current finding is supported by other works [33,34] on Schizosaccharomyces and natural chabazite respectively by using immobilization technique for bioremoving of Cu, Co, Zn and Ni from industrial wastewaters.

4. Conclusion

It can be concluded that the bio sorption capacity of examined heavy metal ions from industrial wastewater by using immobilized banana beads was very effective in bioremoving such ions from industrial wastewater and in the recovery of these metal ions.

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