Application of *Prosopis Africana* Seed Pods for the Removal of Nickel in Aqueous Solution

*[1]M. A. Khalid, [2]H. M. Wakari, [1]M. Abdullahi, [1]S. I. Gadam, [1]M. J. Musa, [1]I. Ibrahim, [1]M. D. Abba, [1]A. Y. Mahmud and [1]M. Salisu

[1]National Research Institute for Chemical Technology, P.M.B 1052, Zaria, Kaduna State, Nigeria.

[2] Kaduna Refining and Petrochemical Company, Kaduna, Nigeria.

*Corresponding author: musamuizzi@gmail.com

ABSTRACT

The adsorption of Nickel (II) ions from aqueous solution using *Prosopis africana* seed pods as adsorbent was investigated by batch adsorption technique. Adsorption studies indicated that the maximum Ni^{2+} removal was observed at contact time of 60 minutes, pH of 2, adsorbate concentration of 30 mg/l and adsorbent dose of 1g. At these optimized conditions, 92% Ni^{2+} were removed.

Keywords: Adsorbent, adsorption, nickel, *prosopis africana*, seed pods

INTRODUCTION

Protection of the environment is evidently a necessity for mankind in order to survive and enjoy a pleasant life in the future. Water is one of the basic elements of life and the importance of its protection from pollution has been recognized for a long time.

Heavy metals, which are natural components of the earth's crust [1], are the most harmful of the thousands of chemical pollutants identified in water [2]. These metals enter the food chain and end up in the human body via ingestion, inhalation and skin contact. About fifty nine elements have been classified as heavy metals [2], and their presence, even at low concentration [3], cause short and long-term effects to animals, plants and humans due to their toxicity [4].

Nickel is one of the heavy metals [5]. It is an important nutrient required by the body in small amount [3], but at high concentration may cause headache, dizziness, nausea, vomiting, chest pain, etc [6]. The main source of nickel pollution is caused by processes such as smelting, mining, and metal finishing [3].

Some conventional techniques for the purification of wastewater containing Ni^{2+} are chemical precipitation, reverse osmosis, and membrane separation processes [7]. Among the several treatment options, adsorption is the most widely recommended due to its convenience, simplicity in design and operation [3]. Furthermore, adsorption removes high solute loading pollutants from wastewater even at dilute concentrations [8].

Prosopis africana is flowering plant specie of the genus *Prosopis* found in Africa [9]. Rural populations use different parts of the plant for different purposes. The wood is used in the manufacture of household items, the roots and bark are used in traditional medicine, the leaves and pod pulps in fodder, and the seeds in food [10]. Seeds of *Prosopis africana* are used in Nigeria to prepare traditional fermented soup condiment or as flavour enhancers. Its common names include African mesquite and iron tree [9].

In this report, the ability of *Prosopis africana* seed pods to remove Ni^{2+} ions from aqueous solution by varying pH, contact time, adsorbate concentration and adsorbent dose was investigated.

MATERIALS AND METHODS

Preparation of adsorbate (Nickel solution)

A stock solution of Ni^{2+} was prepared by dissolving 4.048g of Nickel chloride ($Nicl_2.6H_2O$) in 1000 ml deionized water. Other concentrations were obtained by successive dilutions.

Preparation of adsorbent (*Prosopis africana* seed pods)

Prosopis africana seed pods were obtained from Kasuwan Mata, Sabon Gari Market, Zaria, Kaduna State, Nigeria. The seeds were removed from the pods by shelling. The pods were washed with deionized water, dried in room temperature for seven days, ground and sieved to particle size of 710µm. It was then oven dried at 105°C for 1 hour.

Adsorption experiment

All experiments were conducted at room temperature. Batch experiments were conducted at pH of 2-10, adsorbate concentration of 10-100mg/l, adsorbent dose of 1-5g and contact time of 20-100 min. Each working volume of adsorbate concentration was pipette into 350 ml flask and topped up to 50 ml with deionized water. Batch test was carried out by shaking Ni^{2+} solution with *Prosopis africana* at varying pH and contact time. The solution was filtered and filtrate was taken for atomic absorption spectrophotometer (AAS) analysis to determine the final concentration of Nickel. The percent removal of Nickel was evaluated as follows [11]:

% Adsorption of Ni^{2+}= $\frac{c_i - c_f}{c_i} \times 100 \ldots\ldots\ldots\ldots (1)$

ci and cf stands for the initial and final Ni^{2+} concentrations.

RESULTS AND DISCUSSION

Percent Nickel removal as a function of pH

Figure 1 represents the change in % Ni^{2+} removal with change in pH while keeping other variables constant. As the pH was increased from 2-6, adsorption increased from 78.9-92.0%. Beyond pH of 6, however, there was gradual decrease in adsorption reaching a value of 77.6% at pH of 10.

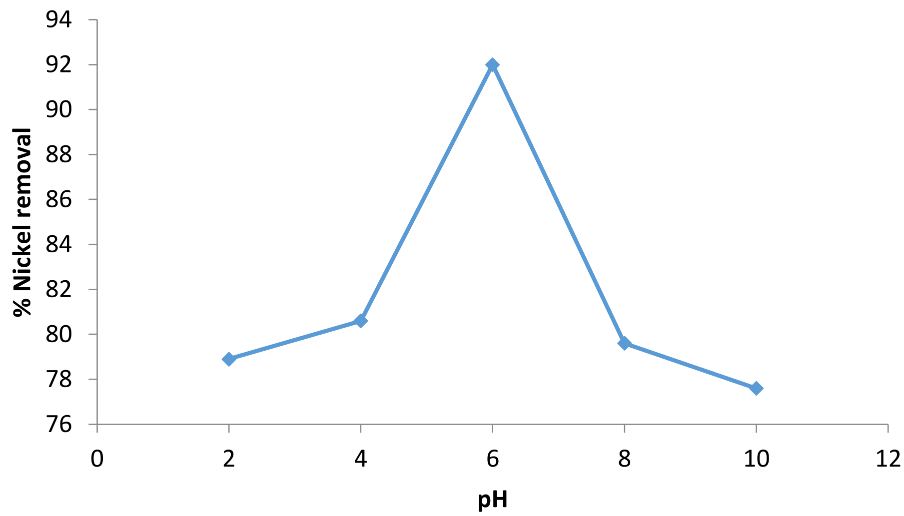

Figure 1: Percent Nickel removal against pH

The pH plays a significant role in metal adsorption [12] as it influences surface properties of the adsorbent by dissociation of functional group and surface charges [6]. At low pH, metal cations and protons compete for binding sites on adsorbent surface resulting in low adsorption [12]. Increasing pH results in more negatively charged ligands attracting more positively charged metal ions [6] and cause an increase in adsorption. Beyond pH of 6, however, adsorption decreased due to reduction in solubility of the Ni^{2+} and its precipitation [12] leading to lower binding.

Percent Nickel removal as a function of adsorbent dose

Figure 2 shows the change in % Ni^{2+} removal with change in adsorbent dose from 1-5g. From the figure, adsorption of Ni^{2+} ions increased with increase in adsorbent dose.

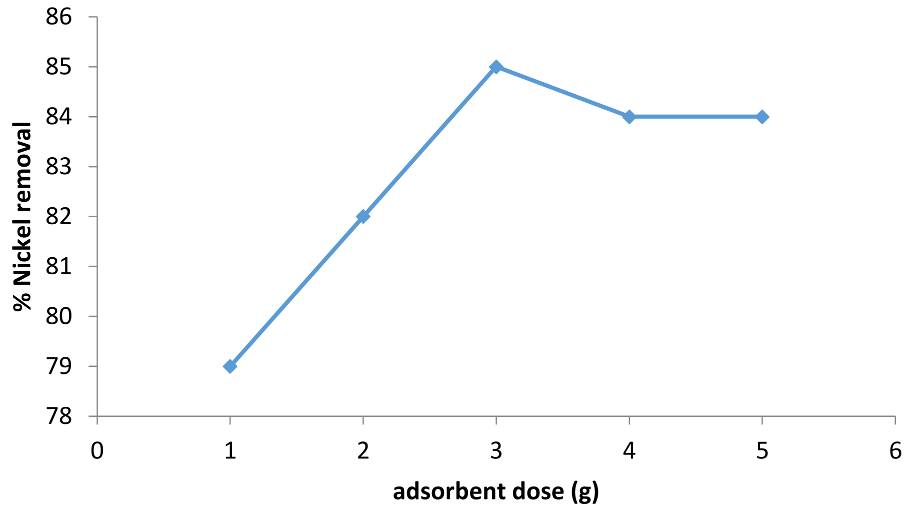

Figure 2: Percent Nickel removal against Adsorbent dose

Adsorption increased from 79-85% when the dose was increased from 1-3g. Beyond 3g, adsorption decreased to a constant value of 84%. The increase in %Ni^{2+} removal at the early stage could be as a result of the increase in adsorption sites [6]. An increase in dose beyond 3g, however, caused no change in adsorption which could be as a result of the saturation of the adsorbate [5].

Percent Nickel removal as a function of time of contact

The change in %Ni^{2+} removal with change in contact time from 10-100 min is shown in Figure 3. From the figure, it was observed that the rate of adsorption was rapid in the first 20 min as more than 90 percent removal of Ni^{2+} occurred.

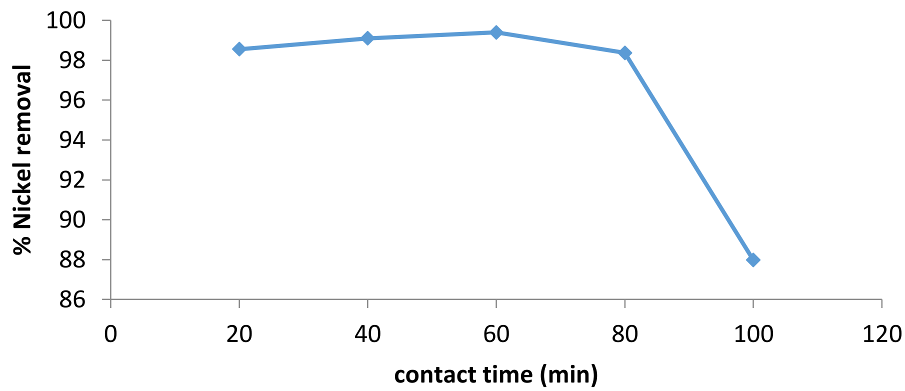

Figure 3: Percent Nickel removal against Contact time

Beyond 20 minutes the rate of adsorption increased but at a slower rate until 60 mins after which adsorption gradually decreased to 87.98% at 100 minutes. Hence 60 minutes was the time required to reach equilibrium. The rapid increase in Ni^{2+} removal at the early stage could be as a result of the availability of vacant sites [12] and the gradual decrease at later stage could be a result of fast exhaustion of the binding sites on reaching equilibrium [13].

Percent Nickel removal as a function of concentration of adsorbate

Figure 4 presents the effect of adsorbate concentration (10-100mg/l) on the adsorption of Ni^{2+} while keeping the other variables constant. Analysis of the figure revealed a rapid increase in the percent removal of Ni^{2+} from 12-92% as the adsorbate concentration is increased from 10-30mg/l.

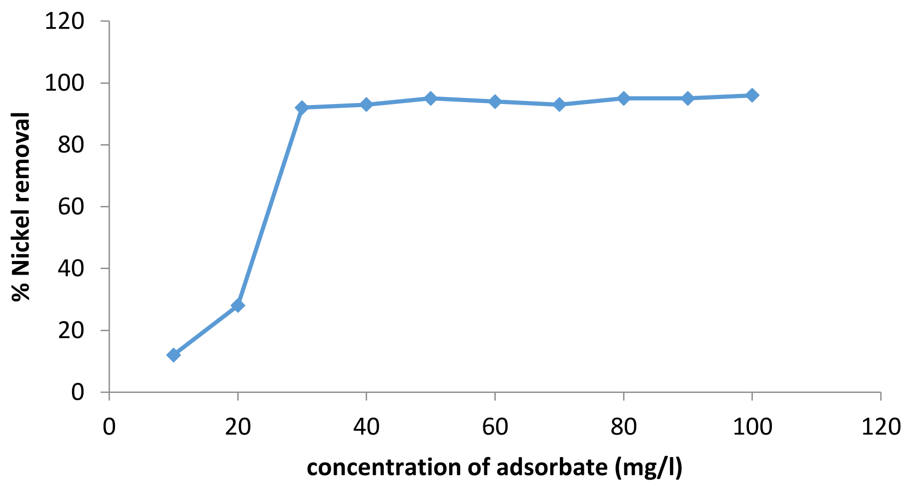

Figure 4: Percent Nickel removal against Concentration of adsorbate

Beyond 30 mg/l, % removal is slightly affected by any increase in the adsorbate concentration which could be a result of the exhaustion of the adsorption sites.

CONCLUSION

The ability of *Prosopis africana* seed pods to adsorb Ni^{2+} ions from aqueous solution was investigated. All the variables (contact time, pH, adsorbate concentration and adsorbent dosage) studied had positive effect on the removal of Ni^{2+} from aqueous solution. At the end of the study and within the experimental range studied 92% Ni^{2+}were removed. Therefore, *Prosopis africana* seed pods can serve as an effective and low cost adsorbent for the adsorption of Nickel (II) ions from aqueous solution.

REFERENCES

1. Ogabiela, E.E., Okonkwo, E.M., Oklo, D.A., Udiba, U.U., Hammuel, C., Ade-Ajayi, A.F. & Mahmud, A. (2011). Status of Trace Metal Levels of Different Age Population of Dareta Village, Anka, Nigeria. *J. Appl. Environ. Biol. Sci*. 1(5), 96-100.
2. Vikashni, N., Matakite, M., Kanayathu, K. & Subramanium, S. (2012). Water Purification Using Moringa and Other Locally Available Seeds in Fiji for Heavy Metal Removal. *Intern. J. Appl. Sci. Technol*. 2(5), 125-129
3. Olubenga, S.B., Kayode, A.A., Olayinka, U.B. & Ibrahim, O.L. (2014). Sequestering Nickel (11) Ions from Aqueous Solutions Using Various Adsorbents: A Review. *Pak. J. Anal. Environ. Chem*, 15(1), 1-17.
4. Varsha, S., Weng, C.H., Singh, V.K. & Sharma, Y.C. (2011). Adsorption of Nickel Ions from Aqueous Solutions by Nano Alumina: Kinetic, Mass Transfer and Equilibrium Studies. *J. Chem. Engn. Data*, 56, 1414-1422.
5. Sumathi, T. & Alagumuthu, G. (2014). Adsorption Studies for Arsenic Removal Using Activated Moringa Oleifera. *Intern. J. Chem. Engn.* http://dx.doi.org/10.1155/2014/430417
6. Sandeep, Y., Varsha, S., Sushmita, B., Fethiye, G. & Yogesh, C.S. (2012). Studies on the Removal of Nickel from Aqueous Solutions Using Modified Riverbed Sand. *Environ. Sci. Pollut. Res.* doi/10.1007/s11356-012-0892-2
7. Senthil, K.P., Ramakrishnan, K. & Gayathri, R. (2010). Removal of Nickel(11) from Aqueous Solutions by Ceralite IR 120 Cationic Exchange Resins. *J. Engn. Sci. Technol*. 5(2), 232-243.
8. Cybelle, M.F., Wan-Chi, T., Shiow-Shyung, L., Kuo-Jung, H., Maria, L.D. & Meng-Wei, W. (2012). Copper, Nickel and Lead Adsorption from Aqueous Solution Using Chitosan-Immobilized on Bentonite in Ternary System. Sustain. *Environ. Res*. 22(6), 345-355.

9. Gbericon, G.M., Agbulu, C.O. & Yaji, M.E. (2015). Nutritional Composition of Fermented Powdered Prosopis Africana Soup Condiment with and without Inocula. *Intern. J. Curr. Microbiol. Appl. Sci*. 4(2), 166-171.
10. Laouali, A., Iro, D.G., Issa, C. & Ali, A. (2015). Fruit Production of *Prosopis africana (G. et perr) Taub*. An Overexploited Species in the South Eastern Niger. *Intern. J. Curr. Microbioj. Appl. Sci*. 4(5), 50-56.
11. Torab-Mostaedi, M., Ghassabzadeh, H., Ghannadi-Maragheh, M., Ahmadi, S.J. &Taheiri, H. (2010). Removal of Cadmium and Nickel from Aqueous Solution Using Expanded Perlite. *Brazilian J. Chem. Engn*. 27(2), 299-308.
12. Manjeet, B., Diwan, S., Garg, V.K. & Pwan, R. (2009). Use of Agricultural Waste for the Removal of Nickel Ions from Aqueous Solutions: Equilibrium and Kinetic Studies. *Intern. J. Civil Environ. Engn*. 1(2), 108-114.
13. Ali, F., Mussa, T., Abdulla, A., Alwan, A. & Salih, D. (2015). Removal of Cadmium from Wastewater Using Low Cost Natural Adsorbents. *Int. Res. J. Environment. Sci.* 4(6), 11-15.