Heavy Metal Removal From Aqueous Solution using Agricultural Waste

Manjeet Bansal*, Diwan Singh**, Sanjiv Aggarwal*** and V.K.Garg****

*Department of Civil Engineering Giani Zail Singh College of Engineering and Technology, Bathinda –151001 (Punjab), India, push_kar5@yahoo.com

**Department of Civil Engineering National Institute of Technology, Kurukshetra - 136119, India, diwansingh@rediffmail.com

***Department of Civil Engineering Giani Zail Singh College of Engineering and Technology, Bathinda –151001 (Punjab), India, sanjiv_aggarwal@rediffmail.com

****Department of Environmental Science and Engineering,, Guru Jambheshwar University of Science and Technology, Hisar 125001, (Haryana), India, vinodkgarg@yahoo.com

* Corresponding Author: Manjeet Bansal

ABSTRACT

The potential of economically cheaper cellulose containing natural materials like rice husk was assessed for nickel adsorption from aqueous solutions. The effects of pH, contact time, sorbent dose, initial metal ion concentration and temperature on the uptake of nickel were studied in batch process. The removal of nickel was dependent on the physico-chemical characteristics of the adsorbent, adsorbate concentration and other studied process parameters. Maximum nickel removal was observed at pH 6.0. The efficiency of rice husk for nickel removal was 51.8% for dilute solutions at 20 g L^{-1} adsorbent dose. The results revealed that nickel is considerably adsorbed on rice husk and it can be an economical method for the removal of nickel from aqueous solutions.

Keywords: Ni(II), Adsorption, Rice Husk, pH, Contact Time

1. INTRODUCTION

Heavy metals are continuously released into the aquatic environment from natural processes like volcanic activity and weathering of rocks. Industrial processes have greatly enhanced the mobilization of heavy metals. The presence of heavy metals in the environment is of major concern because of their extreme toxicity and tendency for bioaccumulation in the food chain even in relatively low concentrations [1], [2]. They are highly toxic as ions or in compound forms; they are soluble in water and may be readily absorbed into living organisms. Nickel(II) containing wastewaters are common as it is used in a number of industries including electroplating, batteries manufacturing, mining, metal finishing and forging. Higher concentrations of nickel cause cancer of lungs, nose and bone. Dermatitis (Ni itch) is the most frequent effect of exposure to Ni, such as coins and jewellery. The higher concentration of Ni(II) in ingested water may cause severe damage to lungs, kidneys, gastrointestinal distress, e.g., nausea, vomiting, diarrhoea, pulmonary fibrosis, renal edema, and skin dermatitis [3]. A number of methods are available for the removal of metal ions from aqueous solutions. These are ion exchange, solvent extraction, reverse osmosis, electrodialysis, precipitation, flocculation and membrane separation processes [4]-[8]. However, these techniques have certain disadvantages, such as high capital and operational costs or the treatment and disposal of the residual metal sludge. Adsorption compared with other methods appears to be an attractive process due to its efficiency and the ease with which it can be applied in the treatment of heavy metal containing wastewater [9]. In recent years, a number of adsorptive materials, such as aquatic plants [10], agricultural by-products [11], industry by-product [4], sawdust [12], clay [13], zeolite [14], and microorganisms [15] were used in heavy metal removal from wastewaters. Agricultural waste materials being economic and eco-friendly due to their unique chemical composition, availability in abundance, renewablity, low cost and more efficiency seem to be a viable option for heavy metal remediation. Present investigation is devoted to study the removal of Ni(II) from synthetics aqueous wastewater by using rice husk. This agricultural byproducts is available in large amount in India and other countries. It is both used as fuel in brick kilns or packing material and available at negligible price. The effect of various process parameter, namely pH, adsorbent doe, initial metal ion concentration, contact time and temperature on the removal of Ni(II) have been investigated. The data may be used full for environmental engineer in designing of heavy metal containing waste water containing treatment systems.

2. MATERIALS AND METHODS

Rice husk was collected from a pre-consumer agricultural product process industry located at Kurukshetra (Haryana). The collected rice husk was dried under sun and impurities were separated manually. It was boiled with distilled water for 5 h to make it free from colored compounds and filtered. The residual material so obtained was dried at 80°C in hot air oven for 24 h, and then the material was grinded and sieved through the sieves of 300μ size. The material was stored in airtight plastic container for further use.

Aqueous solution of nickel (1000 mg L^{-1}) was prepared by dissolving nickel nitrate (AR grade) in double distilled water. The aqueous solution was diluted with distilled water to obtain the working solutions of desired concentration. pH of the solutions was adjusted using 0.01M NaOH/0.01M HCl. The nickel concentration was determined by Atomic Absorption spectrophotometer (Shimadzu 6300, Japan).

For each adsorption experiment, 50 ml nickel solution of 100 mg L^{-1} concentration was used. After adding desired amount of adsorbent (4- 20 g L^{-1}) pH was adjusted in the range of 2.0 – 6.0 and the mixture was agitated on orbital shaker (Scigenics Biotech Orbitek) at 180 rpm for 180 min. After that the mixture was filtered to separate the exhausted adsorbent from solution. The residual nickel concentration in solution was determined by Atomic Absorption spectrophotometer. All experiments were replicated thrice and results were averaged. The removal percentage and adsorbent capacity of adsorbent were calculated as reported by Garg et al [16].

3. RESULTS AND DISCUSSION

A. Effect of pH

Metal biosorption is critically linked with pH. In order to establish the effect of pH on the adsorption of Ni(II) onto adsorbent, the batch adsorption studies at different pH values were carried out in the range of 2.0-6.0. No studies was done beyond pH 6.0 because of the precipitation of the Ni(II) as its hydroxide (Fig. 1). From results it is evidence that maximum adsorption of Ni(II) was 51.4% at pH 6.0. pH of the solution play a very important role in the metal uptake. Both adsorbent surface metal binding sites as well as metal chemistry in solution are influenced by solution pH. At low pH values, metal cations and protons compete for binding sites on adsorbent surface which results in lower uptake of metal. It has been suggested that at highly acidic condition, adsorbent surface ligands would be closely associated with H_3O^+ that restricts access to ligands by metal ions as a result of repulsive forces. It is to be expected that with increase in pH values, more and more ligands having negative charge would be exposed which result in increase in attraction of positively charged metal ions [17]. In addition at higher pH the lower binding is attributed to reduced solubility of the metal and its precipitation[18].

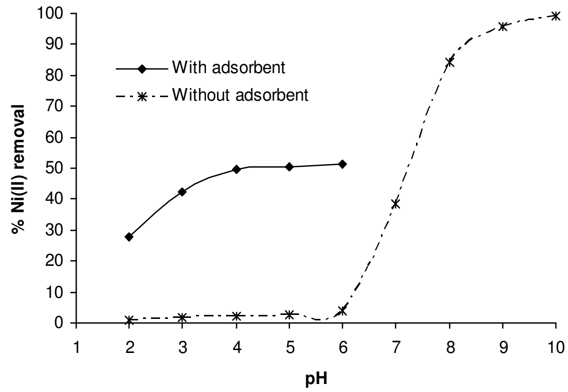

Fig. 1 Effect of pH on Ni(II) removal [Ni(II) conc = 100 mgL^{-1}; adsorbent dose = 20.0 g L^{-1}; contact time = 180 min; stirring speed = 180 rpm; temp = 25°C

B. Effect of adsorbents dose

Effect of biosorbents dosage on percentage removal of Ni(II) was investigated by varying adsorbents dosage in the range of 4.0 g L^{-1} to 20.0 g L^{-1}. It was observed that the percentage removal of Ni(II) increases with the increase in the adsorbent dosage (Fig. 2). The maximum percentage removal of Ni(II) was 51.8% at 20.0 g L^{-1} of biosorbents dose and constant initial metal ion concentration of 100 mg L^{-1}. The phenomenon of increase in percentage removal of Ni(II) with increase in adsorbent dose may be explained as with increase in adsorbent dose, more and more surface becomes available for metal ion to adsorb and this increase the rate of adsorption [4]. Table I shows the uptake capacity at different adsorbent doses.

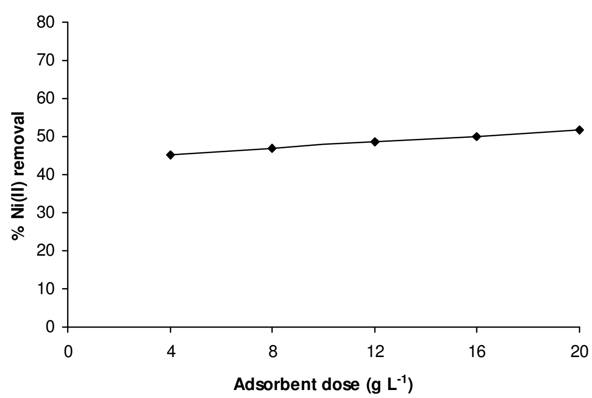

Fig. 2 Effect of adsorbent dose on Ni(II) removal [Ni(II) conc = 100 mg L^{-1}; pH= 6.0; contact time= 180 min; stirring speed= 180 rpm; temp= 25°C]

C. Effect of contact time

Fig. 3 shows the effect of contact time on the extent of adsorption of Ni(II). It has been observed that adsorption rate increased from 30.3% to 51.8% with increased in contact time from 10 to 180 min. Maximum

Ni(II) removal was achieved within 120 min after which Ni(II) concentration in the test solution became constant. It may be explained by the fact that initially for adsorption large number of vacant sites was available, which slowed down later due to exhaustion of remaining surface sites and repulsive force between solute molecule and bulk phase [19].

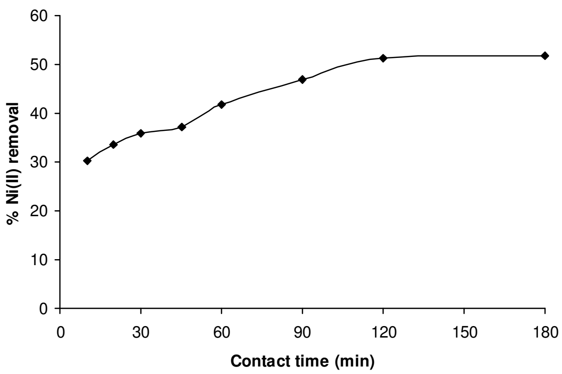

Fig. 3 Effect of contact time on Ni(II) removal [Ni(II) conc = 100 mg L^{-1}; pH = 6.0; adsorbent dose = 20.0 g L^{-1}; stirring speed = 180 rpm; temp = 25^{o}C]

D. Effect of initial metal ion concentration

Fig. 4 shows the effect of initial metal concentration on the adsorption experiment. It was observed that adsorption of Ni(II) decreased from 82.5% to 30.5% with increased in metal concentration from 5 to 500 mg L^{-1}. At higher concentration, most of the Ni(II) are left unabsorbed due to saturation of adsorption sites. As the ratio of sorptive surface to ion concentration decreased with increasing metal ion concentration and so metal ion removal was reduced. At low initial concentration of metal ions, more binding sites are available. But as the concentration increases, the number of ions competing for available binding sites in the biomass increased [20].Table I shows the uptake capacity of adsorbent at different initial concentration of nickel ions.

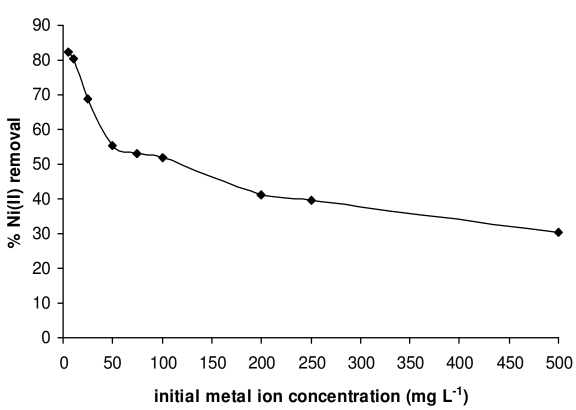

Fig. 4 Effect of initial metal ion concentration on Ni(II) removal [adosorbent dose = 20.0 g L^{-1}; pH = 6.0; contact time = 180 min; stirring speed = 180 rpm; temp = 25^{o}C]

E. Effect of temperature

Fig. 5 shows the effect of temperature on the adsorption of Ni(II). From the results it is evident that there is gradual increase in the removal percentage from 46.9% to 65.4%. The above results also showed that the adsorption was endothermic in nature. Since adsorbent is porous in nature and possibilities of diffusion of adsorbate cannot be ruled out therefore, increase in the sorption with the rise of temperature may be diffusion controlled which is endothermic process, i.e. the rise of temperatures favors the adsorbate transport with in the pores of adsorbent [21].

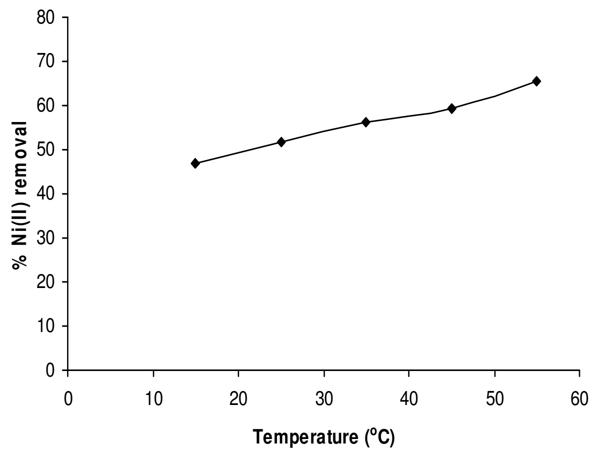

Fig. 5 Effect of temperature on Ni(II) removal [Ni(II) conc = 100 mg L^{-1}; adsorbent dose = 20.0 g L^{-1}; pH = 6.0; contact time = 180 min, stirring speed = 180 rpm]

TABLE I

Adsorption capacity of adsorbent at different initial nickel concentrations and different adsorbent doses

Parameter	Adsorption Capacity(qe,mg g^{-1})
Initial nickel conc (mg L^{-1})	
5	0.21
10	0.40
25	0.86
50	1.39
75	1.98
100	2.59
200	4.11
250	4.94
500	7.63
Adsorbent dose (g L^{-1})	
4	11.3
8	5.86
12	4.06
16	3.13
20	2.59

4. CONCLUSIONS

The effect of various process parameters showed that percent adsorption decreased with increase in initial metal ion concentration while it increased with increase in adsorbent dose. Maximum nickel removal by adsorbent was at pH 6.0. Results in the present study showed that rice husk can be used for the removal of nickel ions from dilute wastewater.

REFERENES

[1] P. Malakul, K.R. Srinivasan, and H.Y. Wang, "Metal adsorption and desorption characteristics of surfactant-modified clay complexes", Ind. Eng. Chem. Res., 37, 4296–4301, 1998.

[2] D. Mohan, and K.P. Singh, "Single and multi-component adsorption of cadmium and zinc using activated carbon derived from bagasse—an agricultural waste", Water Research, 36, 2304–2318, 2002.

[3] A.K. Meena, G.K. Mishra, P.K. Rai, C. Rajagopal, and P.N. Nagar, "Removal of heavy metal ions from aqueous solutions using carbon aerogel as an adsorbent", J. Hazard. Mater., 122, 161–170, 2005.

[4] M. Rio, A.V. Parwate, and A.G. Bhole, "Removal of Cr^{6+} and Ni^{2+} from aqueous solution using bagasse and fly ash", Waste Manage., 22, 821–830, 2002.

[5] V.K. Gupta, C.K. Jain, I. Ali, M. Sharma, and V.K. Saini, "Removal of cadmium and nickel from wastewater using bagasse fly ash—a sugar industry waste", J. Colloid Interface Sci., 271-2, 321–328, 2003.

[6] E. Remoudaki, A. Hatzikioseyian, K. Tsezos, and M. Tsezos, "The mechanism of metals precipitation by biologically generated alkalinity in biofilm reactors", Water Res., 37-6, 3843–3854, 2003.

[7] Y.C. Sharma, G. Prasad, and D.C. Rupainwar, "Removal of Ni(II) from aqueous solutions by sorption", Int. J. Environ. Studies, 37, 183–191, 1991

[8] G. Yan, and T. Viraraghavan, "Heavy metal removal in a biosorption column by immobilized M. Rouxii biomass", Bioresour. Technol., 78, 243–249, 2001.

[9] B. Volesky, and Z.R. Holan, "Biosorption of heavy metals", Biotechnol. Progr., 11, 235–250, 1995.

[10] N.R. Axtell, S.P.K. Sternberg, and K. Claussen, "Lead and nickel removal using Microspora and Lemna minor", Bioresour. Technol. 89, 41–48, 2003.

[11] M.E. Argun, and S. Dursun, "Removal of heavy metal ions using chemically modified adsorbents", J. Int. Environ. Appl. Sci. 1, 27–40, 2006.

[12] M.E. Argun, S. Dursun, C. Ozdemir, and M. Karatas¸ "Heavy metal adsorption by oak sawdust: thermodynamics and kinetics", J. Hazard. Mater., 141, 77–85, 2007.

[13] G.E. Marquez, M.J.P. Ribeiro, J.M. Ventura, and J.A. Labrincha, "Removal of nickel from aqueous solutions by clay-based beds", Ceram. Int., 30, 111–119, 2004.

[14] E. Alvarez-Ayuso, A. Garcia-Sanchez, and X. Querol, "Purification of metal electroplating waste waters using zeolites", Water Res. 37, 4855–4862, 2003.

[15] F.B. Dilek, A. Erbay, and U. Yetis, "Ni(II) biosorption by Polyporous versicolor", Process Biochem. 37, 723–726, 2002.

[16] U.K. Garg, M.P. Kaur, V.K. Garg, and D. Sud, "Removal of Nickel (II) from aqueous solution by adsorption on agricultural waste biomass using a response surface methodological approach", Biores. Technol., 99-5, 1325-1331, 2008.

[17] K.C. Sekher, S. Subramanian, J.M. Modak, and K.A. Natarajan, "Removal of metal ions using an industrial biomass with reference to environmental control", Inter. J. Miner. Process 53, 107-120, 1998.

[18] J.L. Zhou, and R.J. Kiff, "The uptake of copper from aqueous solution by immobilized fungal biomass", J. Chem. Technol. Biotechnol. 52, 317-330, 1991

[19] R. Saravanane, T. Sundararajan, and S. Sivamurthyreddy, "Efficiency of chemically modified low cost adsorbents for the removal of heavy metals from wastewater: A comparative study", Indian J. Env. Hlth. 44, 78-81, 2002.

[20] R. Gupta, and H. Mohapatra, "Microbial biomass: An economical alternative for removal of heavy metals from waste water", Indian J. of Exp. Biol. 41, 945-966, 2003.

[21] E.I. El-Shafey, "Behaviour of reduction-sorption of chromium(VI) from an aqueous solution on a modified sorbent from Rice Husk", Water air and soil poll. 163, 81–102, 2005.