

# BIOSORPTIVE NICKEL REMOVAL – AN INSIGHT INTO STUDIES AND RESEARCH

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## Abstract

Heavy metal from waste water can be removed by various physical, chemical and biological treatment methods. Nickel is one of the important heavy metal emitted from electroplating, battery, and catalyst industries. Biosorption of Nickel is effective and low cost treatment technique. It uses agricultural waste and there by reduces solid waste problem to a considerable extent. The method has unique advantage in its ability to adopt for different geographical areas according to availability of agricultural waste. The investigations show that the agricultural waste such as banana, mosambi peels, ground nut, coconut shells and rice husk has been used for Nickel removal with satisfactory to excellent results. By using these materials the percentage Nickel removal to the extent of 99 percent was observed by investigators. Also aspects such as isotherms, kinetics, modeling of this process are area of study for researchers because of the role of these aspects in optimum and effective removal of Nickel. Present review summarizes studies and research on biosorptive removal of Nickel from waste water.

**Keywords:** Concentration, Percentage Removal, Isotherm, Kinetics, Equilibrium.

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## 1. INTRODUCTION

Wastewater treatment by effective and economical method is gaining increasing importance in current era of industrialization. The sustainable development calls for effective treatment of wastewater. Organic matter and heavy metals are two major pollutants in industrial effluents. Removal of various pollutants from wastewater can be carried out by various physical, chemical and biological treatments. Various investigators have used biological treatment methods for removal of organic matter[1,2,3]. Also physico-chemical treatments such as adsorption, membrane separation and electro dialysis find application in removing organic matter and heavy metals[4,5,6]. Heavy metal removal can be carried out various biological and non biological methods. Biological methods are classified as attached growth and suspended growth. Activated sludge process(ASP) is most widely used suspended growth method[7,8,9].

Trickling filters[TF] can be used for applying attached growth method. It has been used by number of investigators for removal of various pollutants such as organic matter and heavy metals [10,11,12].The investigation on nickel removal by using physical, chemical and physico-chemical treatments like adsorption, coagulation, membrane separation, electro dialysis have also been reported[13,14].Biological treatments have advantage in terms of cost and effectiveness. Biosorptive removal of nickel has wide potential and scope for research[15]. The reason may be availability of wide variety of low cost materials. The present review is an attempt to have insight

into this method aimed at understanding the methodology, mechanism, kinetics, isotherms and effectiveness.

## 2. REVIEW ON BIOSORPTIVE NICKEL REMOVAL

Seshadri et.al. studied application of citric acid modified bark powder as biosorbent to remove Ni (ii) from waste water[16]. They studied various parameters like concentration, adsorption dose, contact time along with isotherm and kinetic study. The maximum removal efficiency of nickel (II) ion was found to be 98.96% at the dose of 0.4 g for contact time for 10 minutes. Langmuir adsorption isotherm model and pseudo-second order model explained the metal uptake process. Saeed et. al. worked on removal of toxic metallic ions from waste water of tanneries. They used punica granatum (pomgranate) membrane for this purpose [17]. A comparison of heat treated p. granatum membranes and acid treated p. granatum membranes (with conc. HNO<sub>3</sub>) were conducted. They prepared adsorbent by physicochemical treatment. Adsorption capacity was investigated using batch experiments. The effect of adsorption time was also investigated and the experimental data obtained was analyzed. They observed that biosorption of metallic ions on chemically treated p. granatum membranes/peels with HNO<sub>3</sub> at 873K and chemically treated p. granatum membranes/peels with H<sub>3</sub>PO<sub>4</sub> + ZnCl<sub>2</sub> mixture at 873K shows an increasing trend in case of Ni(II) ) removal. Abbasi et.al. worked on adsorptive removal of CO<sup>2+</sup> and Ni<sup>2+</sup> by peels of banana from aqueous solution[18]. They investigated the pH, adsorbent dose, time and concentration.

The optimum values for pH and adsorbent dose were observed to be 5.5, 3 grams/l respectively. 3 minutes of contact time was enough for maximum removal. Also adsorption capacities of banana peel increased with increasing the equilibrium metal ion concentration. Malkoc and Nuhoglu carried out investigations on treatment for nickel(II) reduction from aqueous solutions. They used tea factory waste[19]. They carried out batch and column studies at various operating conditions. They observed that the sorption process fits the Langmuir isotherm model. They were able to remove 82.4 % Ni at an optimum pH value of 4.

The study carried out by Amiri et. al. explored the adsorption potential of heavy metals including nickel by *elaegnus angustifolia* fruit powder effluent water[20]. They studied the effect of parameters like pH value of solution, sorbent amount, initial metal ion concentration and contact time on Nickel removal. In their investigation, they used new sorbent prepared from *elaegnus angustifolia* fruit and pretreated it with distilled water. They estimated Nickel loading based on mass balance through loss of metal from aqueous solution. The optimum Nickel removal of 61% was obtained at initial pH of 2. The optimum contact time required was observed to be 70 minutes and Nickel uptake followed Langmuir isotherms. Gonen and Serina obtained a low cost adsorbent from orange peel. [21]. The biomaterial was pretreated with distilled water and crushed to finer size and used for investigation. They used the spectrophotometric method for Nickel analysis. They obtained maximum adsorption at pH 5. The sorption capacity of biosorbent increased rapidly in first 14 minutes and then attained equilibrium. Hence the equilibrium time was observed to be 14 minutes. With increase in adsorbent dose from 0.05 to 0.2 g/100 ml under the optimized conditions, the adsorption increased from 9.67 to 33.14%. According to their studies both, Langmuir and Freundlich model can be used for studying isotherms. The solute uptake followed second order kinetics.

Muthusamy et.al. used nonhazardous agro-waste materials like maize cobs as an adsorbent for nickel removal[22]. They studied effect of parameters like initial concentration, adsorbent dosage, contact time and agitation speed on nickel removal with adsorption isotherms. There was an increase in the adsorption initially and then it was stable. They observed an increase in the biosorption percentage with dosage of biosorbent upto certain level followed by decreasing trend. Also it was observed that a contact time of 90 minutes was needed to achieve equilibrium. As agitating rate was increased from 100 to 400 rpm, adsorption capacity of maize cob increased and then decreased. Freundlich isotherm fitted better than Langmuir. Mustaqem et. al. used activated carbon prepared from behda, anjan, chinch, bakam neem leaves for Nickel removal and carried out comparative studies for various parameter like initial metal concentration, particle size, pH and contact time[23]. The leaves of Behda, Anjan, Chinch and Bakam Neem were washed, dried, grounded to finer size and pretreated with acid. They conducted batch experiments to study the

impacts of particle size. They observed that there was decrease in the size of the particle. pH value of 7.0 was optimum for Nickel (II) removal. The adsorption decreased with increase of initial metal ion concentrations. The equilibrium data fitted well with both Langmuir and Freundlich models of adsorption.

Kumar and Kirthika used leaf powder to adsorb nickel[24]. They studied the influence of experimental parameters on adsorption. They also investigated kinetics of adsorption and applied model for the kinetics of nickel adsorption onto BT leaf powder. Langmuir, Freundlich and Temkin equations were used for analyzing the data. They obtained maximum 60.21% removal for nickel. Pseudo-second-order rate equations described the kinetics of adsorption. The BT leaf was found to have a high potential for the removal of Ni<sup>2+</sup> from wastewater. Gohulavani and Andal evaluated *azaridachta indica* seed shells for Ni (II) adsorption[25]. In their investigation, they obtained maximum adsorption capacity 67 mg/g. They used FT-IR spectroscopy for analysis. They also observed the chemical modification after chromium biosorption. According to the investigation, the ions initially present in the seed shell, such as phosphorus, calcium, iron etc. were removed during the Nickel sorption process. The value of correlation coefficient R<sup>2</sup> was relatively high. The morphological changes and metal binding capacity of the employed adsorbent was indicated in the SEM and FT-IR analysis.

Chemically activated pouteria sapota seed(SPSSC) and commercially available carbon(CAC) was used by Rani et. al. for nickel removal [26]. They treated pouteria sapota seeds carbon with sulphuric acid before using it for the nickel removal. In the batch experiments they studied, effect of equilibration time, pH, and carbon dosage for the removal of Nickel. They used nickel sulphate for preparation of synthetic effluent. They observed that there was increase in removal efficiency with contact time. The percentage nickel removal was 80 for SPSSC and 74 for CAC. They studied effect of adsorbent dose by varying it from 50 mg/l to 500mg/l. 100- 150 milligram per 100 ml of adsorbent was optimum for the effluent. They were able to recover 79% of SPSSC and 74% CAC by 0.1 N HCl. Einollahipeer and Pakzadtoochaei carried out an investigation aimed at investigating the potential of cocopeat for removal Ni and Zn from aqueous solutions[27]. In their investigation, they used cocopeat material. They preheated the material separately with 0.4 mol/l NaOH, 0.4 mol/L HNO<sub>3</sub> and distilled water. They calculated efficiency and q index given by equation 1 and 2. The adsorption of nickel was observed at pH 5-6. They also found that the coconut peat modified by acid was having highest nickel removal. At adsorbent dose of 3 grams, q value was 44 mg/g with almost 100 percent nickel removal. The adsorption was single layer as it obeyed Langmuir isotherm.

$$\text{Efficiency} = \frac{C_0 - C_s}{C_0} \times 100 (\%) \quad (1)$$

$$q = \frac{(C_0 - C_s)}{m} \quad (2)$$

Co: is the metal ion's first concentration (before adsorption) by mg/l

Cs: is the second concentration of the metal ion (after adsorption) by mg/l

M: is the sorbent mass by grams

q: amount of adsorbed metal ion on sorbent adsorption's unit.

An investigation carried out by Krishna was focused on the use of powder of Mosambi fruit peelings (PMFP). He selected it as it was low cost material with excellent adsorption possibilities for heavy metal removal [28]. The sample size he used in study was 50 ml of effluent. He also considered influence of usual affecting parameters. For analysis of nickel, he used spectrophotometric method with dimethylglyoxime (DMG) reagent. He observed increase in adsorption with pH. Adsorption decreased with increase in pH up to 6. Hydrogen and nickel ions compete for sorption sites. This inhibits nickel adsorption. Also he found that the equilibrium time was 90 minutes for nickel removal. 100% adsorption was observed by him with 200 mg of adsorbent dose for 50 ml effluent. He also observed that the decrease in particle size increases the metal uptake. Correlation Coefficient( $R^2$ ) was found to be 0.9962 for Langmuir isotherm indicating excellent agreement. Freundlich isotherm was also satisfactory with  $R^2$  value 0.94.

Fruit wastes were used as biosorbents by Schiewer and Patil [29]. They preferred pectin rich fruit wastes. They carried out kinetic and equilibrium studies for removal of various metals from effluent. They collected fruit waste of pectin rich fruits like lemon peels, orange peels, grapefruit peels, apple peels, apple kernel, apple core, and grape skins. For pH 3 and 5, the linearized second-order plot of  $t/q$  against  $t$  resulted in straight lines. The solute uptake followed second order model. They also observed that equilibrium was reached within 30–90 minutes. Langmuir isotherm was followed by some equilibrium data. They concluded that the fruit material rich in pectin is an excellent biosorbent material. Adsorption studies on Ni(II) using powder of papaya seeds was carried out by Krishna and Swamy[30]. They carried out experiments in batch scale to study influence of various parameters like initial metal ion concentration, pH, agitation time, particle size and adsorbent dosage for Nickel removal. They washed, soaked and dried papaya seeds before using for Nickel removal from water. According to their observation 0.6 mm was optimum particle size. They also observed that the adsorption decreased with pH, it increased with adsorbent dose and decreased with initial metal ion concentration. The adsorption also followed pseudo first order kinetics. They concluded that heavy metal removal by using papaya seeds can be very fruitful method in developing countries for effluent from small to medium industry. It promised economical, feasible and eco-friendly and user friendly solution to heavy metal pollution.

### 3. CONCLUSIONS

Many investigators have obtained encouraging results for nickel removal by biosorption. Various waste materials such as banana, mosambi peels, ground nut, coconut shells and rice husk has been used with moderate to excellent result. It

was observed in most of the studies that Langmuir adsorption isotherm model and pseudo-second order model was followed by nickel uptake process. Also acidic conditions favoured adsorption. Nickel removal to the extent of 99 percent was obtained in some investigations. It can be concluded that biosorption at optimum operating conditions is viable option for nickel removal.

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