# Removal of Nickel From Industrial Wastewater Using Natural Adsorbents: A Review

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***Abstract-*** *The wastewater coming from industries like metal plating, tanneries, mining operations, electroplating, fertilizers, pesticide and battery industries are contaminated with heavy metals. One of the heavy metals, Nickel is used as raw material mainly in electroplating and metal plating industries. The methods which are used to remove nickel from waste water are adsorption, ion exchange, coagulation / flocculation, membrane separation, electrocoagulation, floatation and biological methods. Adsorption method has been found as the best method among the other conventional methods for treating the industrial waste water and reducing the amount of nickel ions present in them. The naturally and locally available materials are used as adsorbents to remove nickel. The objective of the paper is to review various such materials used as adsorbent. The results of important parameters such as adsorption capacity, concentration of nickel ions, adsorbent dosage and contact time were discussed along with Langmuir and Freundlich isotherm and adsorption kinetics.*

***Keywords***- Nickel removal, low cost natural adsorbents, batch test, Langmuir and Freundlich Isotherm, Adsorption Kinetics

## I. INTRODUCTION

Excessive release of heavy metals from the industrial effluents is a major threat to both environment and the health of people [1]. The wastewater coming from industries like metal plating, tanneries, mining operations, electroplating, fertilizers, pesticide and battery industries are contaminated with heavy metals [2]. Nickel is one of the major heavy metal whose increased concentration causes various diseases like gastrointestinal problems, blood disorders, giddiness, nausea, vomiting, diarrhea, shortage of breathe, headache, dermatitis, skin irritation, damages to kidneys, liver problems and temporary problems in the eye [3]. Electroplating industry is a major source of nickel. In these industries, concentration of nickel in effluent ranges from 3.4 to 900 mg/l [4]. But, the permissible discharge level of it is only 0.1 mg/l [5]. Therefore, it is necessary to reduce the concentration of nickel from effluent before releasing it to the environment. There are various conventional methods available for reducing it. They are adsorption, ion exchange, coagulation / flocculation, membrane separation, electrocoagulation, floatation and biological methods. Many researchers have studied these methods and have found that the adsorption method is more effective as compared to the other methods. In order to make this method more effective and economical many attempts were made to prepare adsorbents from natural materials. Such materials are orange peel, durian rind, banana peel, mosambi peel, coconut coir, coconut shell, carrot peel, tamarind shell, palm shell, corn cob, maize cob, rice husk, saw dust, neem bark charcoal, coffee, tamarind and tur dal husk, peat, moringa oleifera seeds and coconut leaves. The objective of the paper is to review adsorption efficiency of the materials from different research papers.

## II. ADSORPTION

Adsorption is the adhesion of atoms, molecules or ions from a gas, liquid or dissolved solids to a surface. It is the deposition of molecular species onto the surface. The molecular species that gets adsorbed on the surface is known as the adsorbate and the surface on which the adsorption occurs is known as adsorbent.

## III. METHODS OF NICKEL REMOVAL

The various methods for removal of nickel like adsorption, chemical modification, ion exchange and reverse osmosis were reviewed. An extensive list of materials like mosambi fruit peelings, maize cob, rice husk, saw dust, activated clay, tea waste, ceralite IR 120, biomass, polymer sulphonate materials, etc. were used as adsorbents for removal of nickel. It was concluded that the adsorption method was more effective for removal of nickel. The choice of the method to be used is reported that it depends on the concentration of the effluent, nature of the effluent, percentage removal and material required. (Sonali R. Dhokpande, et al., 2013).

## IV. ADSORBENT MATERIALS

### ORANGE PEEL AS AN ADSORBENT

Pectin which is present in the adsorbents have the capacity to adsorb nickel to a great extent which makes orange peel a very good adsorbent. In this research, the synthetic nickel solution is prepared using nickel sulphate. Orange peel of size 0.3 to 0.5 cm was used. Batch test was performed and it was found that for varying adsorbent dosage of 2 to 6 gms and about 21% of nickel was removed for a contact time of 120 minutes (Sonali R. Dhokpande and Jayant P. Kaware, 2016). Orange peel of size 1.8mm was used for batch adsorption test with nickel nitrate as stock solution. The maximum adsorption was found at pH 5 with the adsorption dosage range of 0.05 to 0.2g. The efficiency correspondingly increased from 9.67 to 33.14% (Ferda Gonen and D. Selen Serin 2012).

**DURIAN RIND AS AN ADSORBENT**

Methylene Blue and Brilliant Green stock solutions were prepared which were treated with the durian rind to find the adsorption efficiency of nickel. The highest and lowest removal efficiency for Methylene Blue solution was observed to be 52.87% and 23.57% respectively. Similarly, for Brilliant Green, it was 97.81% and 87.79% respectively (Syakirah Afiza Mohammed et al.,).

**BANANA AS AN ADSORBENT**

For a contact time of 150 minutes, about 31% of nickel was removed on varying the dosage from 2 to 6 gms of banana peel (Sonali R. Dhokpande and Jayant P. Kaware, 2016). The powder of dried banana peel and nickel nitrate were used for performing the adsorption test. It was found that at pH of 5.5 and for contact time of 3 minutes maximum adsorption was observed and the maximum efficiency was found to be 74% (Zahra Abbasi al., 2013).

**MOSAMBI AS AN ADSORBENT**

About 31% of nickel was removed on varying the dosage of mosambi peel of size 0.3 to 0.5 cm from 2 to 6 gms with a contact time of 150 minutes removed (Sonali R. Dhokpande and Jayant P. Kaware, 2016).

**COCONUT COIR AS AN ADSORBENT**

Coconut coir pith was used to reduce the concentration of nickel from synthetic solution of nickel sulphate. It was found that efficiency increased upto 75.8781% at 5g. However, optimum condition was at pH 6 with a contact time of 120 minutes and adsorbent dose of 2g. The characteristics of the adsorbent were studied using SEM analysis where the metal binding process was observed using the shift in wavelength (Sheel Ratan, et al., 2016)

**COCONUT SHELL AS AN ADSORBENT**

Coconut shell carbon was used for removing various heavy metals like Ni, Cd, Pb and Zn. The optimum conditions for nickel were found to be pH 9, dosage 45gms and concentration of 2 mg/l. The maximum efficiency was found to be in the range of 80 to 87% (Hamidi A. Aziz, et al., 2005).

**TAMARIND SHELL AS AN ADSORBENT**

Tamarind shell was collected, dried, powdered and sieved to a size of 80 mesh size. Then, adsorption test was conducted and it was observed that maximum amount of nickel was removed on treating it with HCl at pH 4, at a temperature of $40^0$C with an initial concentration of 125ppm. The maximum efficiency was found to be 98% (Ashwin Shenoy, et al., 2015).

**CARROT PEEL AS AN ADSORBENT**

The capacity of carrot peel on removing nickel from its synthetic solution of nickel sulphate was tested. Maximum adsorption capacity was found to be 98% which was obtained on treating it with NaOH as well as treated distilled water at $35^0$C and $40^0$C respectively. The optimum pH was 4 with an initial concentration of 162.5ppm (Ashwin Shenoy, et al., 2015).

**PALM SHELL ACTIVATED CARBON AS AN ADSORBENT**

The activated carbon of palm shell was used for removing nickel from a synthetic solution of nitric acid obtained from the company, Fisher Scientific, UK. The maximum adsorption capacity of nickel was found to at a dosage of 1g. It was obtained within a time of 75 minutes and recorded 55% removal (Y. B. Onundi, et al., 2010).

**CORN COB AS AN ADSORBENT**

Pulvarized and sieved corncob was taken and treated with nickel sulphate. The test was conducted in UV – Double Beam absorption spectrophotometer. It was found that for 6g of adsorbent dosage about 70.8% of nickel was removed. The optimum pH was 6 with a contact time of 90 mins for varying adsorbent dosage of 0.5 to 5 g/l. The maximum adsorption was found to be 86.08% for 25 ppm (Arunkumar C. et al., 2014).

**MAIZE COB AS AN ADSORBENT**

Maize cob was used as an adsorbent for removing nickel ion form industrial wastewater. The test was conducted using nickel sulphate as synthetic solution. The adsorption of nickel was recorded at 232.0 nm. For metal concentration from 1 to 10 mg/l with adsorbent dosage from 0.5 to 5 g and contact time of 30 mins the binding capacity was higher (Muthusamy P. et al., 2012).

**RICE HUSK AS AN ADSORBENT**

Rice husk was used as a cost – effective material for removing nickel. It was observed that about 51.8% of nickel was removed for a pH of 6. The contact time was found to be 180 minutes (Bansal M. et al., 2009).

**SAW DUST AS AN ADSORBENT**

The capacity of Polymer Loaded Saw Dust (PLSD) as an adsorbent was analysed in removing Ni(II) ions by batch adsorption method. The saw dust was chemically modified by treating it with 60% of Poly Sodium 4 – Styrene Sulphonate (PSSS) after carbonating it. Then, batch adsorption was carried out. SEM and BET analysis, FTIR spectrum were performed from these tests it was found that, PLSD removes more that 90% of the Ni(II) ions at pH 5 (Lahieb Faisal Muhaisen, 2017). Saw dust of size 0.6mm was used. The optimum condition was at pH 6 with a contact time of 120 minutes. The removal efficiency was as high as 94.6% (Tajun Meera Begum KM, et al., 2016).

**NEEM BARK CHARCOAL AS AN ADSORBENT**

The adsorptive capacity of Neem Bark Charcoal (NBC) and Commercially Activated Carbon (CAC) on removing nickel from its aqueous solution was compared. Neem barks were collected, dried and powdered. The adsorption capacity was measured using UV spectrophotometer. 50 ppm was found to be the optimum concentration for the test and the results showed better results for CAC due to the increase in surface area (L Lisy and L Subha, 2016).

**COFFEE, TAMARIND AND TUR DAL HUSK AS AN ADSORBENT**

Coffee, tamarind and tur dal husk were used as biosorbents. The adsorption efficiency was found to be 98% under the optimum conditions of pH 3 for coffee husk, 96% at pH 5 for tamarind husk and 93.7% at pH 3 for tur dal husk. The adsorbent dosage was 2.5g for a contact time of 90 minutes and varying concentration of 0 to 100 mg/l (Dhananjay Chaturvedi and Omprakash Sahu 2014).

**PEAT AS AN ADSORBENT**

Peat was used as a low cost adsorbent for removing nickel(II) and lead(II) from its synthetic solution, nickel nitrate hexahydrate. For Ni(II) at pH 9, the removal efficiency of 92.5% was obtained. The removal percentage increased to 94.2% for adsorbent dosage of 5g (Przemyslaw Bartezak, et al., 2015).

**MORINGA OLEIFERA SEEDS AS AN ADSORBENT**

Dried and pulverized seeds of moringa oleifera were used for removing nickel from aqueous solution. It was reported that for a pH range of 4 to 6 and adsorbent dosage of 2 g and contact time of 5 mins about 90% of Ni(II) was removed (Marques TL, et al., 2012).

**COCONUT LEAVES AS AN ADSORBENT**

Coconut leaves were dried and powdered. It was treated with pure nickel metal dissolved in HCl. The maximum removal efficiency of Ni(II) was found to be 93.18% for 2.0g of coconut leaves at pH 8.0 in optimum time of 4 hours (Rudre Gowda, et al., 2012).

## V. LANGMUIR AND FREUNDLICH ISOTHERM

The study of the process of adsorption is usually described through graphs known as the adsorption isotherm. The graph is drawn between concentration and adsorbent dosage at constant temperature, which gives the nature of adsorption process. The Langmuir model explains a monolayer adsorption while the Freundlich explains multilayer adsorption.

Both the isotherms gave very good results in case of banana peel whereas for mosambi and orange peel wastes as it shows both the monolayer and multilayer adsorption, only Freundlich isotherm gave better results [6]. Coconut coir pith showed a monolayer adsorption pattern and thus provided the best fit for Langmuir isotherm [9]. Freundlich isotherm was a best fit than the Langmuir isotherm as far as the Polymer Loaded Saw Dust (PLSD) was concerned [16]. Orange peel powder was found to have a better fit with Freundlich isotherm than the Langmuir model [4]. For banana peel powder the Langmuir isotherm was a good fit and showed monolayer isotherm [8].The comparative study done with Neem Bark Charcoal (NBC) and Commercially Activated Carbon (CAC) showed better correlation with the Langmuir

isotherm [18]. Freundlich isotherm is more efficient in removing nickel from synthetic industrial wastewater as it showed monolayer adsorption while using palm shell activated carbon as an adsorbent [13]. Maize cob showed multilayer isotherm and satisfied Freundlich isotherm better than Langmuir isotherm [14]. Langmuir isotherm was a better fit for saw dust of size 0.6 mm [17]. When peat was used as an adsorbent co – efficients of correlation were found to be 0.991 and 0.986 for Langmuir and Fruendlich isotherm respectively [20]. For corn cob, both Langmuir and Freundlich isotherms were favourable [13]. Rice husk satisfied both Langmuir and Freundlich isotherm [15]. Durian peel was a better fit for Langmuir model than Freundlich model [7]. Moringa Oleifera seeds were a better fit for Langmuir isotherm [21]. Coffee husk, tur dal and tamarind husk followed both Langmuir and Freundlich isotherm [19]. Both the Langmuir and Freundlich equations fitted when coconut leaves where used for removing nickel [22].

## VI. ADSORPTION KINETICS

Adsorption kinetics is defined as the rate of adsorption of a molecule onto a surface i.e., the efficiency of adsorption. The adsorption rate is largely dependent on the physio – chemical parameters of both adsorbent and the adsorbate. Various kinetic models are used by researchers, where the pseudo first order and second order kinetics are discussed here. In the first order kinetics, the rate of reaction is directly proportional to the difference between equilibrium concentrations of the adsorbate, whereas, in second order kinetics, it is proportional to the square of the difference between equilibrium concentrations of the adsorbate [20].

Coconut coir pith satisfied both the pseudo – first order and second – order kinetics [9]. Adsorption kinetics showed better fit for pseudo second order than pseudo first order kinetics for Polymer Loaded Saw Dust (PLSD) [16]. Orange peel powder showed a complex adsorption process as it fits pseudo – second order kinetic model [4]. The adsorption kinetics was found to be linear for both Commercially Activated Carbon (CAC) and Neem Bark Charcoal (NBC) under different conditions [18]. Saw dust with size of 0.6 mm followed pseudo – second order kinetics [17]. Peat [20], Rice husk [15] and Coconut leaves[22] satisfied the pseudo second order model.

## VII. CONCLUSION

The researchers have used several agricultural waste materials as a adsorbent for removing nickel from waste water samples. The parameters which influence the removal efficiency such as adsorption capacity, concentration of nickel ions, adsorbent dosage and contact time were presented. The maximum efficiencies of the adsorbents were found using Langmuir and Freundlich isotherm (plot between concentration and adsorbent dosage), pseudo first order and second order reactions. Wastewater treatment using natural adsorbents is still under laboratory scale and in research there is a big scope to treat and reuse the wastewater and bring zero waste disposal.

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