Removal of Ni ion by using Banana peel and their comparison with chemical modification as an bio-adsorbent

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Abstract:

Because of their poisonous nature and inability to biodegrade, heavy metals have developed into a significant water pollution problem. Banana peel was created as a bioadsorbent in this study to filter out heavy metals from tainted water. The primary issue with banana peel bioadsorbent is that, in comparison to its commercial equivalent, activated carbon made from biomass sources has negligible adsorption capacity. In addition, a substantial amount of banana peel wastes adds to the challenge of disposal.Thus, by transforming banana peels into bioadsorbent, the current effort is anticipated to address the issues associated with banana peel disposal. The creation of a bioadsorbent made from banana peels and an evaluation of its effectiveness in adsorbing heavy metals are the goals of this study. We also used various parameters for test of Ni removal ability of bio-adsorbent like including optimizing of pH, temperature of solution, dosage of adsorbent, contact time and solid-liquid ratio.The extensive use of inexpensive raw materials as bioadsorbent in wastewater operations is strongly advised due to their simple processing, widespread availability, and environmental friendliness.

DOI Number: 10.14704/NQ.2022.20.12.NQ77226 **NeuroQuantology2022;20(12): 2453-2462**

Introduction:

Heavy metal ions are used in a variety of industrial processes, including metal finishing, electroplating, painting, dyeing, photography, surface treatment, and the production of printed circuit boards. The majority of heavy metal ions have well-known poisonous and carcinogenic tendencies, and when they are released into the environment without being treated, they pose a hazard to human health as well as substantial harm to the aquatic ecosystem (1–4).After iron, oxygen, magnesium, and silicon, nickel is the fifth most plentiful element. Although Ni belongs to the periodic table's transition series and is susceptible to corrosion from air, water, and alkalis, it readily dissolves in dilute oxidising acids. Only a small portion of the Ni that enters the environment through anthropogenic and natural processes eventually accumulates in plants (5,6). Nickel has a greater chance of entering the food chain since it is frequently mobile and may move to seeds and leaves. Higher Ni concentrations in plants have detrimental effects on both humans and animals (7). High concentrations of toxic metals that might harm human and animal health by contaminating the food chain can be stored in hyperaccumulator plants.

Many methods are reported for removal of heavy metal ions such as precipitation reduction, solvent extraction (8,9)and membrane processes (10). However,these methods have several disadvantages like incompletemetal removal and toxic sludge generation. New method of removing heavy metals by bio-adsorbents presents an important breakthrough (11,12). Bioadsorption can be defined as the ability of biological materialsto accumulate heavy metals from wastewater through metabolicallymediated or physico-chemical pathways of uptake. This phenomenon,defined as bioadsorption, seems to be a good alternative to the existingmethods since it does not produce chemical sludge, it could be highlyselective, more efficient, easy to operate, and hence cost effective forthe treatment of large volumes of wastewaters containing low pollutantconcentrations (13,14).

The use of fruit peels as adsorbents become more beneficial to economic and ecological point of view because these materials can be obtained at lower price, minimizing accumulation of agro-waste, providing possibility of regeneration of the adsorbent and the ability to extract metals from adsorbents. Banana peel, which makes up 30–40% of the weight of the fruit and is one of the most consumed fruits in the world, is the principal residue (15). Banana peel (hence referred to as BP) is a common waste that is rich in cellulose and minerals. Large amounts of BP result in significant disposal issues and significant resource waste. It has been established that a variety of functional groups found on the BP surfaces, including carboxyl, hydroxyl, and amide groups, are an essential component in the biosorption processes. At 41.37%, it also contains carbon (16). By reclaiming it as sorbent, the disposal of BP may be handled in an appealing manner. Purified and treated BP has been utilised as a sorbent to extract dissolved heavy metals from wastewater because of its porous structure and variety of surface groups (17). The pure BP still has to undergo chemical treatment with alkaline and acid due to its poor adsorption ability. In this paper, for the elimination of Ni which is a hazardous heavy metal ions from aqueous solutions and industrial wastes, several research groups have employed raw and chemically processed BP and banana stalks (18). Fresh BPs were employed as raw materials in the current study, and they were subsequently treated with acidic and basic solutions at various concentrations to create effective bioadsorbent.(19) As a consequence, BP bioadsorbent with functional groups on the surface that contain oxygen was produced and they are examined for the removal of heavy metals.

Keywords: Banana Peels, Nickel ion, Removal Ni ion, Bio-adsorbent.

Materials and methods

Banana peel adsorbent creation: The banana peel (BP) was obtained at a nearby market and washed twice or three times with distilled water to remove impurities and dust particles. It was then chopped into tiny pieces and allowed to naturally dry in sunlight-exposed open air. In order to remove humidity and make crushing easier, the peels were roasted in an oven at 120°C. The particles larger than 0.150 mm in diameter were then removed using a crushing process and simply one sieve. The finished solid mass was then stored in a desiccator until needed.

Bio-adsorbent amendment using various chemicals:

For the activation of bio-adsorbent, referred as ABP, the solid support is combined with 1 N nitric acid solution in a weight-to-volume ratio of 1/2 so that it may undergo a 24-hour thermochemical treatment at 120 °C. The surplus acid was then removed from the combination using distilled water, and the waste acid was removed by filtering the mixture overnight in a 1% solution of $NaHCO_3$. The strong support was then dried in an oven at 105°C (20). For the activation, 200 g of the BP are combined with 1 litre of 0.1 M caustic soda solution (referred to as BBP) and let to sit for 24 hours before being washed with distilled water until a neutral pH is reached (21,22). Following that, the NaOH-treated material was dried in an oven at 105 °C. 200g of BP are then combined with 1 litre solution of 0.1M $FeSO_4$ solution(referred as MBP).

Making a Nickel solution:

To generate a solution containing 1 gm/L of Ni(II) ion, 0.4400 g of $NiCl_2.6H2O$ was dissolved in one litre of water and then added to distilled water in a 250 mL standard flask. From the stock solution, different concentrations of Ni ions (25-250 mg/L) were prepared in 250 mL standard flasks and made to mark.

Setting up an experiment to remove and analyse Ni:

The tests for Ni ion adsorption from aqueous solution were performed at room temperature utilising the batch process approach. Initial Ni (II) concentrations in the range of 25, 50, 100, 150, 200, and 250 mg/L were created. Each Ni(II) aqueous solution of the necessary concentrations was put to a 100 ml flask for the adsorption tests.

With the addition of 0.1 N (or 1 N) HNO_3 and 0.1 N (or 1 N) NaOH, the pH of BP, ABP,BBP, and MBP was adjusted. These 100 ml flasks were shaken for two hours at 200 rpm. The experimental parameters used in the batch tests were changed to account for the effects of pH, biosorbent dose and size, starting Ni(II) concentration, contact duration, agitation speed, temperature, and peel pretreatment.

By changing the BP weight between 0.2 and 2 g, the impact of the adsorbent mass was examined. Additionally, the nickel adsorption capacity of BP was investigated at various contact times with Ni ion solutions (10 min, 20 min, 30 min, 45 min, 1 h, and 2 h). In all cases, the starting concentration of metal ion solutions (25 mg/L), pH (pH - 6), and temperature (40°C) were held unchanged.

% Removal and Metals Uptake Capacity Assessment

The Ni ion uptake was calculated using the concentration difference technique (19). The quantity of metal ion (mg) that is absorbed per g (dry weight) of BP is known as the adsorption capacity, or q. The volume of the utilised metal ions solution is V(L), the initial concentration of metal ions is Ci (mg/L), the equilibrium concentration of metal ions in solution is Ce, and the weight of the adsorbent is W(g).

The following equations were used to calculate the %metal uptake by the sorbent and adsorbent capacity at equilibrium q_e (mg = g).

$$\%Adsorption = \frac{(C_i - C_e)100}{C_i}$$

$$q_e = \frac{(C_i - C_e)V}{1000}W$$

Results and Discussion:

The effect of particle size of Bio-adsorbent: The bio-particle sorbent's sizes had a significant impact on its sorption capacity because they changed the overall surface area available for the sorption of metal ions. The effect of changing the sorbent particle size on the sorption capacity, q, revealed that smaller particles removed more Ni(II) than larger ones. The sieve analyzer produced various sizes of bio-adsorbent. With smaller bio-adsorbent particles, equilibrium was attained more quickly than with bigger ones. This was most likely caused by the rise in total surface area, which gave the metal ions additional sorption sites. (20-21,23).

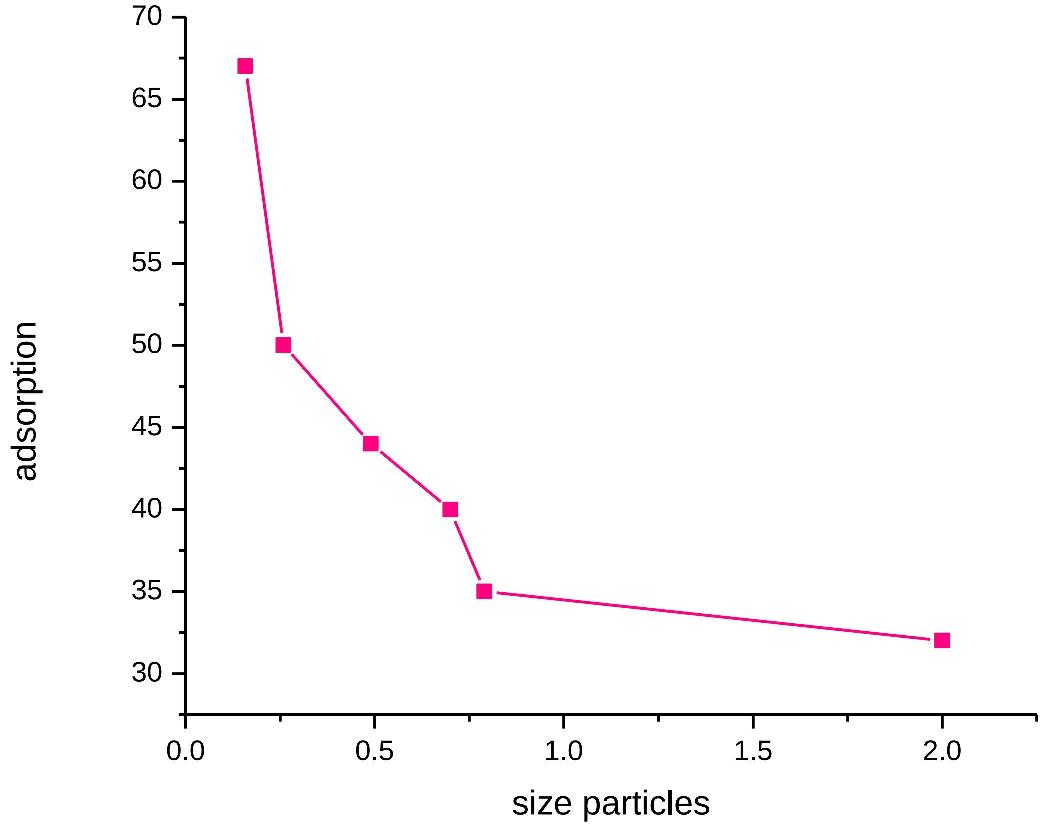

Figure 1: The effect of particle size of Banana peel

The impact of primary treatments: For two hours, 25 mg/L of Ni(II) were shaken at 200 rpm with 0.1 g/L of pretreated bio-adsorbent with a size of 0.155 mm at pH 6 for Ni(II) to assess the impact of pretreatment on Musa Sapientum waste biomass. Figure 2 displays the q values of untreated, physically and chemically altered Musa sapientum waste biomass for Ni(II) sorption. The sorption capacity of the biomass has risen due to the removal of mineral matter and the introduction of new sorption sites on the biomass surface during the boiling process. Due to the loss of intracellular absorption, heating of biomass reduced the metal uptake.(24).

Two elements are crucial in determining the sorption capacity of a certain biomass following acidic pre-treatment-Due to the ionisation of organic and inorganic groups, the polymeric structure of biomass surfaces exhibits a negative charge (25–27), and at a certain concentration, acids can increase the surface area and porosity of the initial sample, enhancing the absorption capacity of biomass (23,28). Similar to how the bio-adsorbent absorption capacity was influenced by two parameters following basic pretreatment. In addition to removing lipids and proteins that cover up reactive sites and purifying the biomass, it may also damage autolytic enzymes (27,29–33). In addition, after a specific alkali concentration, the number of protein amino groups that may participate in metallic ion binding significantly reduced. Theoretically, deproteinization ought to decrease metal retention (23–24, 27, 28–33).

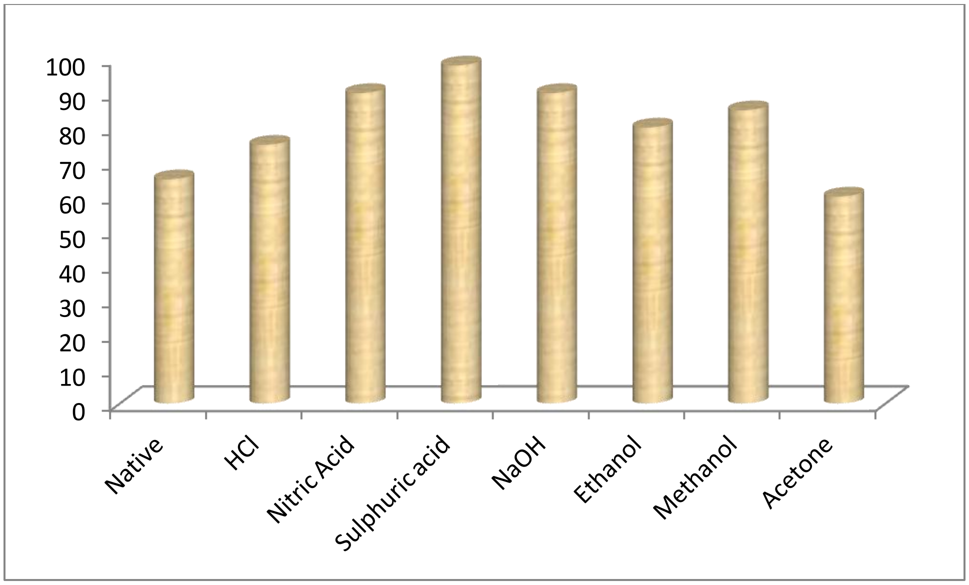

Figure 2: The effects of pre-treatment

Effect of pH on adsorption of Nickel ion:

The dried banana peel used as an experiment to determine how pH affects nickel adsorption. For this, mix 100 ml of 25 mg/L Ni ion solution with 0.1 g of dried banana peel and 0.1 g of chemically altered banana peel powder (particle size: 0.160 mm). Using 1 N HNO_3 or 1 N NaOH to modify the pH between 3 and 10, samples were shaken for 8 hours at room temperature at 200 RPM. BP are then combined with 1 liter solution of 0.1M $FeSO_4$ solution (referred as MBP) and the effect of pH is absorbed. The pH of the solution affects the adsorption of metal ions on adsorbents.

Additionally, it affects the functional group dissociation and surface charge of the adsorbents' surfaces (20, 21). With a rise in solution pH, the Musa sapientum waste biomass's adsorption capacity improved.Because the surface active sites of the adsorbent were protonated, the competition between Ni ion and H^+ for the same surface active sites resulted in extremely low nickel uptake. The Ni ion uptake increased with rise in pH from 3-6 at fixed biomass content (0.05 gm/L) (Fig. 3). It can be seen that the Ni ion's adsorption effectiveness is lowest at pH- 3, and it improves up to 94% at pH- 6.

The Ni ions uptake reduced as pH increased more. Below pH- 6, low adsorption percentage removal is expected and can be explained by a number of factors, including (a) repulsion between the sorbent's positive charge and free Ni ions, (b) competition between free Ni ions and H^+ for the sorbent's active sites, and (c) a reduced ability to form complexes with metal ions as a result of protonation of surface functional groups.

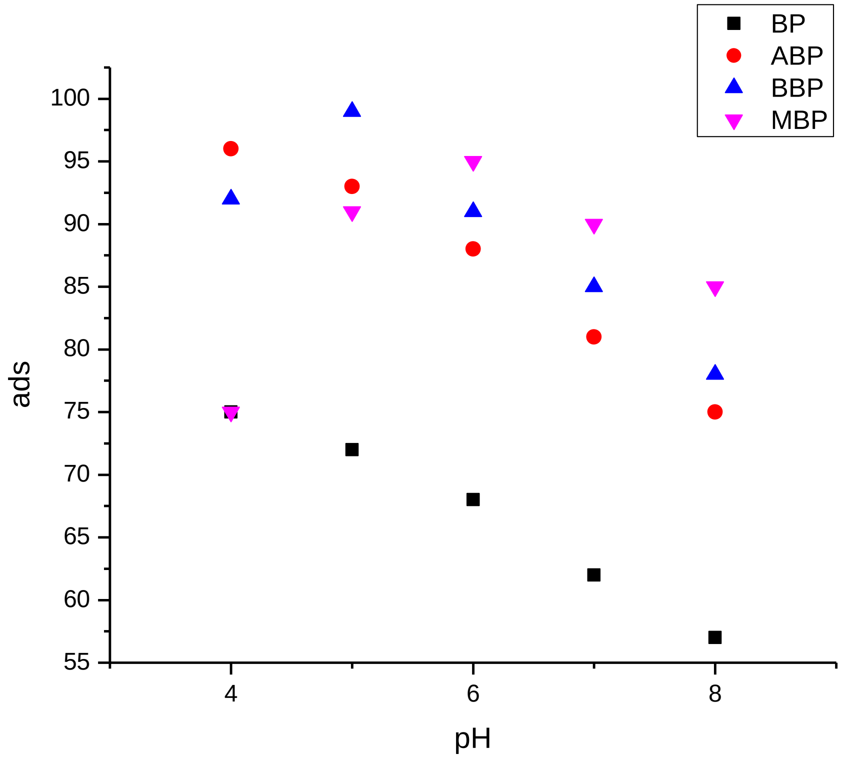

Figure 3: The effect of pH on adsorption of Ni ion

Adsorbent dosage effecton adsorption of Nickel ion: The elimination of Ni ions from aqueous solution was shown in Figure 4 as a function of the mass of modified and unmodified BP. For 100 mL of nickel ion solution, the adsorbent dosages ranged from 0.01 to 0.1 g. Other factors, such as pH (6), contact duration (2 hours), and temperature of 40 ˚C, were held constant.The findings demonstrate that when adsorbent mass grows, Ni ion removal percentage correspondingly rises, however adsorption capacity falls (Fig. 4). This is because there are more active sites available for interaction with metal ions as a result of increasing the dosage of modified and unmodified BP. Consequently, an increase in the proportion of metal ions removed from the aqueous solution. On the other hand, aggregation of modified and unmodified BP inside greater doses of adsorbent can lead to unsaturation of active sites, which can lead to a reduction in adsorption capacity. Aggregation causes a reduction in the total surface area of the adsorbent.

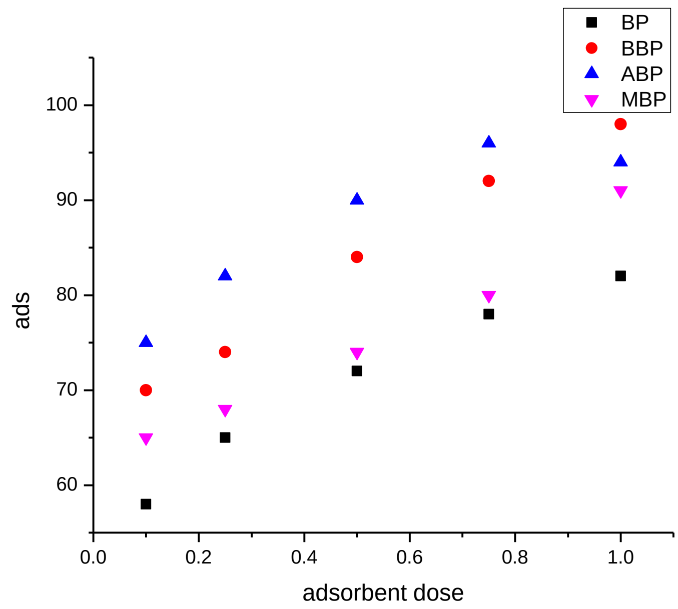

Figure 4: The effect of adsorbent dose on removal of Ni ions

Contact time impacton adsorption of Nickel ion: The impact of contact duration on the removal of nickel by banana peels is depicted in Figure 5. The curve has a classic saturation curve form. The three support ports activated by caustic soda (NaOH), nitric acid, $FeSO_4$ and other substances had very quick Ni ion adsorption, with saturation occurring in within the first five minutes.The adsorption is substantially slower for the natural support, and saturation takes around 10 minutes to attain. This is explained by the initial vacancy of the adsorption sites, which makes it simple for metallic ions to readily occupy them and provide a high adsorption rate. The delayed adsorption beyond this first time may be caused by a slower diffusion of dissolved species via the pores of the adsorbent.

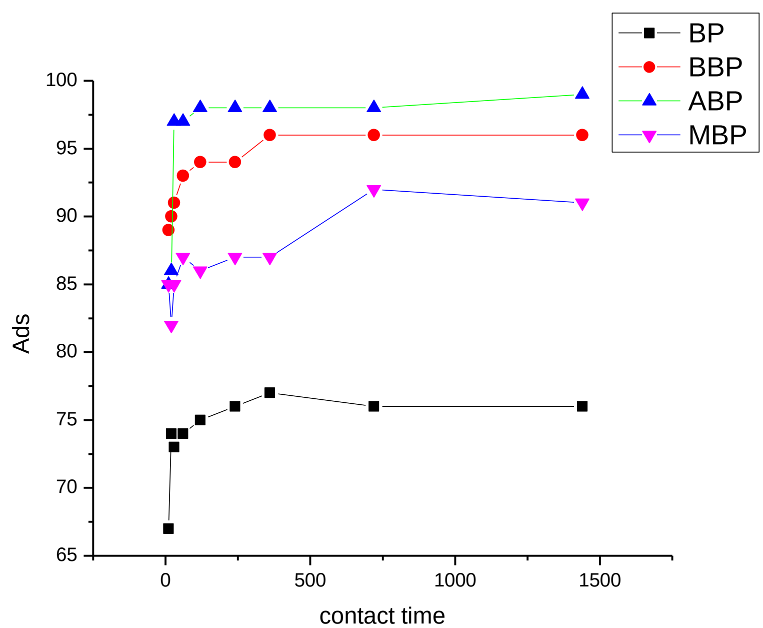

Figure 5: The effect of contact time on adsorption of Nickel

Effect of temperatureon adsorption of Nickel ion:

The impact of temperature on the Ni(II) adsorption by banana peel is shown in Figure 6. On the metal pre-treated material, the greatest Ni(II) adsorption was attained at 30 °C. The ability of Ni(II) to adsorb increased as the solution temperature increased, showing that the process was endothermic. Temperature rise diminished the thickness of the surface layer of the banana peel and accelerated the pace at which the Ni(II) ions moved from the solution onto the empty sites of the peel.(34)

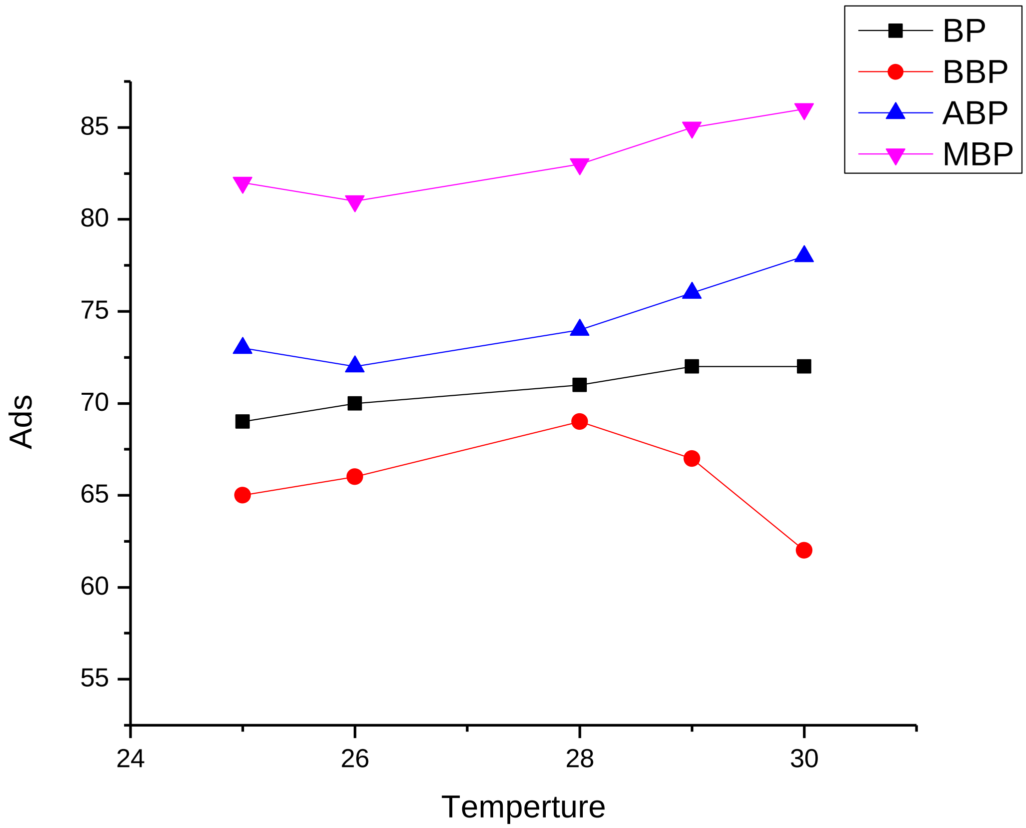

Figure 6: Effect of temperature on adsorption of Nickel ions.

Conclusion: We have created a bio-adsorbent based on banana trash that can remove nickel ions from aqueous solutions. We have a wide range of reaction parameters, such as adjusting the pH, solution temperature, adsorbent dose, contact time, and solid-liquid ratio. The removal of cadmium from banana peel has been proven to be very effective, economically feasible, and inexpensive.

Acknowledgement: We are highly thankful to University of Rajasthan for providing technical assistance and also thankful to Amity University Jaipur for providing the financial support.

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