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Research Article

Nickel (II) Removal from Synthetic Wastewater by Adsorption Using Waste Pea Shell

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Abstract

In this study, the purification of Ni (II) ion in the adsorption process using ground waste pea pod material was investigated. Heavy metal removal from synthetic wastewater, variables such as dose, time, and pH optimization were tried to be determined. The research was carried out in the range of contact time (0-120 minutes), adsorbent amount (50-2000 mg/L), and pH (3-11) during treatment. It was determined that the optimum amount for waste pea pods used as adsorbents in dose optimization was 350 mg. The time optimization made in the mixer determined the optimum time as 60 minutes. Finally, pH optimization was done. Dose optimization, time optimization, and removal efficiency with original pH were found to be approximately 50%. As a result, it has been observed that waste pea pods can be used as a cheap adsorbent for the removal of Nickel (II).

Keywords
Adsorption
Nickel (II)
Optimization
Pea Shell
Synthetic Wastewater

SENTETİK ATIKSUDAN ATIK BEZELYE KABUĞU KULLANILARAK ADSORPSİYON YÖNTEMİYLE NİKEL (II) GİDERİMİ

Özet
Bu çalışmada Ni (II) iyonunun, öğütülmüş atık bezelye kabuğu materyali kullanılarak adsorpsiyon verimi tayin edilmiştir. Sentetik atıksudan ağır metal gideriminde; doz, süre ve pH optimizasyonu gibi değişkenler neticesinde ağır metal giderimi araştırılmıştır. Sabit 120 dakikalık temas süresi dahilinde; adsorban miktarı (50, 150, 250, 500, 1000, 2000 ve yalnızca çözelti), pH (3, 5, 7, 9, 11) ve süre optimizasyonundaki değişkenler (15, 30, 45, 60, 75, 90 ve 120 dakika) seçilerek deneyler yapılmıştır. Doz optimizasyonunda adsorban olarak kullanılan atık bezelye kabuğu için, optimum miktarın 350 mg olduğu saptanmıştır. Karıştırıcıda yapılan süre optimizasyonunda ise optimum süre, 60 dakika olarak belirlenmiştir. Son olarak ise pH optimizasyonu yapılmıştır. Doz optimizasyonu, süre optimizasyonu ve orijinal pH ile giderim verimi %50 olarak bulunmuştur. Sonuç olarak, atık bezelye kabuğunun ucuz adsorban olarak kullanılarak Nikel (II) gideriminde kullanılabileceği bulunmuştur.

Anahtar Kelimeler
Adsorpsiyon
Nikel (II)
Optimizasyon
Bezelye Kabuğu
Sentetik Atıksu

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INTRODUCTION

Water is the most important Source for people to sustain their lives. In recent years, the continuous increase in population, the development of technology, the uncontrolled development of industries, and the increase in industrialization have rapidly reduced and polluted existing water resources. Wastewater is water that has been polluted as a result of domestic, industrial, agricultural, and other activities and its properties have changed partially or completely. When wastewater is left to nature without treatment, it creates negative conditions. Untreated wastewater contains pathogenic microorganisms, nutrients (N and P), organic substances, and dangerous substances. As a result of the decomposition of organic materials contained in wastewater, malodorous gases emerge. These situations increase environmental pollution [1]. Environmental pollution caused by heavy metal ions is among the important problems in terms of human health. Heavy metal ions pose a significant ecotoxicological risk due to their accumulation in living organisms. Metal ions with this toxic effect enter living organisms in different ways [2]. With the definition of heavy metals, the destruction of chemical substances to the ecological system and the environmental problems caused by heavy metals are serious problems. Many metals are considered heavy metals, including lead, cadmium, chromium, iron, cobalt, copper, nickel, mercury, and zinc. These elements, by their nature, are generally found on the earth as stable compounds in the form of carbonates, oxides, silicates, and sulphide or as trapped in silicates. The biggest disadvantage of traditional techniques used in the removal of heavy metals is their low efficiency in attracting heavy metal ions to desired levels [3]. For heavy metal removal, methods such as chemical precipitation, adsorption, electrochemical treatment, and ion exchange, which are among the metal removal methods, are applied. The adsorption method is an effective method that is frequently used in metal removal, as in many toxic organic compounds [4]. Adsorption is a widely used method for removing pollutants from wastewater. It is in a preferred position, especially in terms of its high efficiency in heavy metal removal. Adsorption is the process of attaching atoms, ions, or molecules to a solid surface. The species adsorbed in the adsorption process are called adsorbate. Adsorbates can be one or more. The substance adsorption on its surface is an adsorbent. The main feature of a good adsorbent is that it has a large surface area per unit mass [5]. Many adsorbents are used in the adsorption process. Among them, activated carbon is the most widely used in wastewater treatment all over the world. However, the high cost causes restrictions on its use [6].

The adsorption process takes place in three stages [7].

a) Film diffusion: Soluble molecules penetrate into the adsorbent and form a surface film.

b) Pore diffusion: The solute molecules migrate from the pores of the adsorbent towards the adsorption center.

c) Binding of soluble molecules to the adsorbent surfaces: When the soluble molecules are attached to the pore surface of the adsorbent, adhesion also occurs.

The usage purposes of the adsorption process are as follows: [8].

-Taste and odor removal in wastewater,

-Removal of non-biodegradable pesticides as advanced treatment, phenol, etc. removal of toxic substances from wastewater,

-Removal of detergent residues from water,

-It is used for purposes such as reducing TOC and chlorine needs.

Nickel is one of the main elements in the earth's crust and has been used in industry for nearly a century. It occurs in nature as sulphides, arsenides, and silicates (lateritic origin), mostly with iron. As the most important nickel minerals, nickel (NiAs), cloanthite ($NiAs_2$), pentlandite [(Fe,Ni)S], millerite (NiS), annabergite [$(Ni)3(AsO_4)28H_2O$] can be specified. The most important nickel deposits in the world are in Canada, New Caledonia, Cuba, USA, Australia, Indonesia, and the former Soviet Union. Due to its superior qualities, it is one of the most used metals in the industry [9]. In the industry, nickel refining plants are also involved in the production of electroplating, stainless steel, and nickel-cadmium batteries. Pure nickel is used in electron tubes and in the plating industry. It can form alloys with some metals such as Iron, Copper, Chromium, and Zinc. Stainless steel containing iron and chromium alloy contains 35% nickel [10].

Chemical precipitation is one of these methods in the removal of Ni^{+2} ions in wastewater, and it is based on the formation of hard-soluble salts of heavy metals. Since the solubility of sulfide and hydroxide compounds of Ni^{+2} ions is very low, precipitation can be achieved by adding these ions to such wastewaters. This method is widely used due to its efficiency, low cost, and easy application. However, in sedimentation coagulation systems, heavy metal-containing sludge causing secondary pollution is an environmental defect. For further purification, methods such as membrane processes, filtration, ion exchange, and adsorption are recommended [11].

MATERIAL AND METHOD

2.1 Raw Material

Pea pods were used as adsorbents in the experiment. Belonging to the legume family, the pea is harvested in spring and summer and is known to be a plant species. Its fruit, on the other hand, is physically similar to beans and broad beans, and the peels are separated as waste and are not used. These wastes, whose peels were collected by taking the fruit, were dried in a sun-exposed environment for approximately 45 days. Before starting the adsorption study, these shells were ground in the mill and the particle sizes were pulverized. Then, in order to minimize the negative effect of particle size on the test yield, it was separated from its filamentous tissues by a sieve.

Figure 1. Some pictures taken during the study

2.2. Preparation of Nickel Solution

Nickel (II) Nitrate Hexahydrate ($Ni(NO_3)_2.6H_2O$, Merck CAS No: 13478-00-7, Molecular Weight: 290.79) was used to obtain the heavy metal stock solution in the experiment. In the research study, 1000 mg/L stock nickel solution was prepared and diluted, and used in the experiments.

2.3.Adsorption Experiments and Optimization

Nickel (II) removal experiments were carried out under different experimental conditions. To be used in the experiment, synthetic wastewater was obtained from the prepared stock nickel solution. Within the scope of this research, it was tried to reveal the heavy metal removal efficiency through dose, time, and pH optimizations.

2.3.1 Dose Optimization

In order to determine the dose optimization; 50 mg, 150 mg, 250 mg, 500 mg, 1000 mg, and 2000 mg of powdered pea pods were weighed on precision scales and added to 100 mL flasks. 50 mL of purified wastewater solution was added to the flasks. The mixing time was selected for 120 minutes and kept in a magnetic stirrer at 50-250 rpm at a speed range of 125-150 rpm. The solutions taken from the mixer were diluted 1/10 with distilled water. Then, in order to determine the appropriate adsorbent dose, the measurement was carried out by using nickel kits in the UV-Spectrophotometer Hach Lange DR 2800-3900 model spectrophotometer to read the pollutant concentration. The optimized adsorbent dose was determined as 350 mg (Fig. 1).

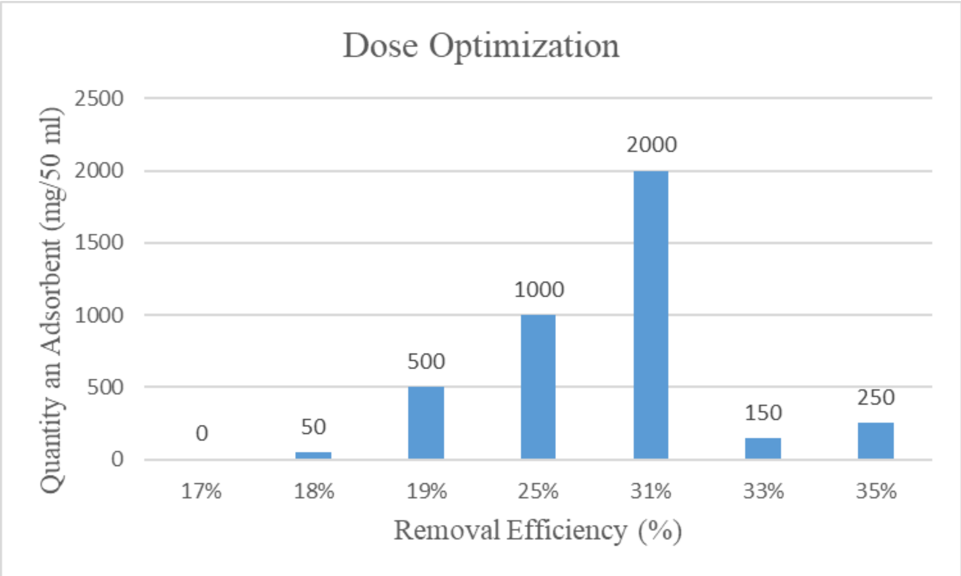

Figure 1. Statistical data on dose optimization

2.3.2 Time Optimization

In the magnetic stirrer to determine the time optimization, waiting times of 15, 30, 45, 60, 75, 90, and 120 minutes were determined. After being kept in a magnetic stirrer at 125 rpm for the required time, the solutions were diluted 1/20 with distilled water, and the pollution concentrations were measured in the UV-Spectrophotometer Hach Lange DR 2800-3900 model spectrophotometer with the help of kits. The optimized time was determined to be 60 minutes at the original pH and 350 mg adsorbent values. (Fig. 2).

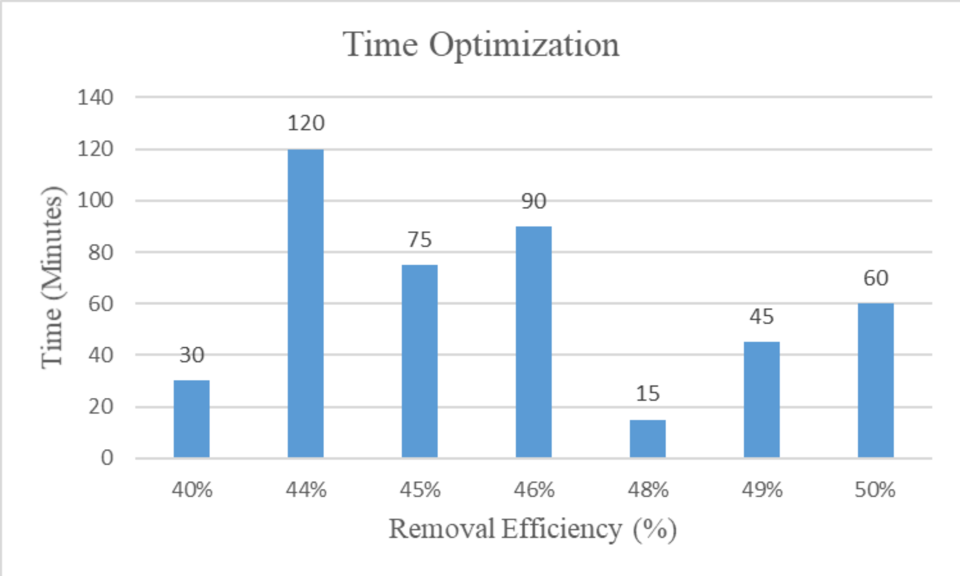

Figure 2. Statistical data on time optimization

2.3.3 pH Optimization

In order to reach the desired pH values, 1 N (HCL) and 1 N (NaOH) were used. For pH optimization; The pH values of 3, 5, 7, 9, and 11 were checked. As a result of time and dose optimizations, 350 mg adsorbent was added to 50 ml stock solutions. After the additions were made, the flasks were placed in the magnetic stirrer and the mixing process was carried out at a speed of 125 rpm for the selected time of 60 minutes. The solutions taken from the magnetic stirrer were diluted 1/20 and the pollution concentrations were measured in the UV-Spectrophotometer Hach Lange DR 2800-3900 model spectrophotometer. The appropriate pH was determined to be 9 (Fig. 3).

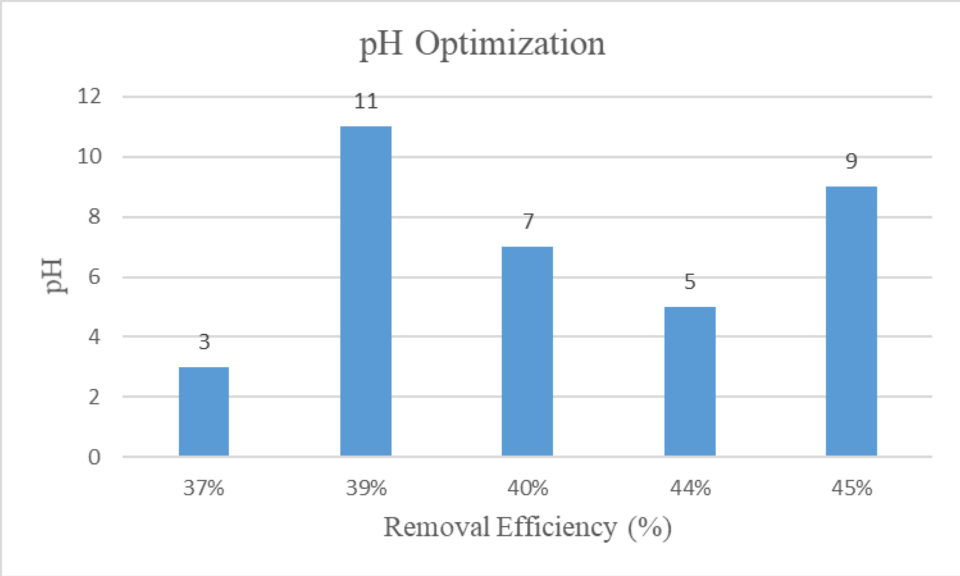

Figure 3. Statistical data on pH optimization

DISCUSSION

3.1. Process Optimizations

The initial concentration was investigated in the range of 0-300 mg/L Ni+2 concentration by keeping the MPA dose constant. As a result of the data generated against the initial metal concentration and the adsorption capacity, it was decided that an initial concentration of 100 mg/L would be appropriate. It was observed that the maximum adsorption capacity was 25.77 mg/g at the initial concentration of 100 mg/L nickel solution. Since the studies in the literature are examined, the metal ion concentration may vary, but the weighted average range is 10-200 mg/L [12-13].

3.2. Effect of Adsorbent Dose, Contact Time, and Stirring Speed

The process waste was obtained from the material discharged from the processes at the colemanite beneficiation plant. With the modified form of this material (MPA), a removal study was carried out by preparing samples at a concentration of 100 mg/L from 100 mL of stock metal solution in a 250 mL flask. It was tried to be determined among the criteria of mixing speed (100-400 rpm), pH (2-10), absorbent dose (0.1-5 g), and contact time (10-150 min). There are different studies on the variety of adsorbent and metal ions used in the research. These are given in Table 1. The amount of adsorbed nickel of the substance added to the heavy metal solution prepared from the stock solution was calculated by the difference in concentration remaining in the solution, and the analysis and samples were carried out simultaneously with the batch method during nickel removal. In the experimental research, studies were carried out in accordance with the standards during the Ni(II) ion concentration, the weighing of the added adsorbent material, and the change of the neutral state. In the study, care was taken to keep all factors that may cause measurement uncertainty and interference under control. Optimization criteria carried out during the research were adsorbent dose, contact/mixing time, pH, and mixing speed, and the temperature was kept constant at 250C under experimental conditions. The sample volume was determined as 100 mL under laboratory conditions. The data obtained were plotted as nickel removal and MPA adsorption capacity. The absorbent dose was studied between 100 mg and 5 g and 800 mg was determined as the most appropriate value. During the determination of the adsorption contact time, it was investigated between 10-150 minutes. At the 40th minute of the experiment, the nickel removal efficiency was approximately 78% and the maximum adsorption capacity of 800 mg MPA was approximately 25.77 mg/g. It was determined that the nickel removal efficiency from synthetic wastewater increased in parallel with the increasing values during the pH study. However, considering the required amount of consumption and cost, the optimum pH value corresponding to the original pH value was determined as appropriate. At pH 6, the adsorption capacity increased by about 2 mg/g. Since the adsorption research was carried out in the intermittent shaking incubator, a range of 100-400 rpm was determined as the mixing speed. During the research, over 80% Ni(II) ion removal efficiency was obtained at 200 rpm. In addition to the increase in the treatment efficiency with the mixing speed, it became difficult to keep the sample in the flask at a high mixing speed in the experimental conditions. Therefore, 200 rpm was determined as the most appropriate value since accepting a value of 400 rpm in field applications will make it difficult to save both electricity consumption and wastewater in the unit [14].

Pollutant Removed	Adsorbents	Removal Efficiency	References
Cr(VI) ve Ni(II)	Pulp and ve Fly Ash	%56-96 ve %83-100	[15]
Ni (II)	Graphite Activated Carbon	%73,6	[16]
Cu^{+2}, Pb^{+2}, Cd^{+2}, Ni^{+2}, Zn^{+2}	Olive Oil Solid Waste	>%85	[17]

Ni(II) ve Cr(VI)	Modified Apricot Kernel Shell	%92	[18]
Cr(VI) ve Cu(II)	Activated Pomace	%98,8 ve %93,2	[19]
Ni (II)	Boron Containing Eggs	%91	[20]
Pb^{+2} ve Ni^{+2}	Waste Containing Boron	%81,86 ve %74,28	[21]
Ni (II)	Waste Pea Shell	%50	Present Study

Table 1. Examples of Different Adsorbent Usage in the Field of Metal Removal

CONCLUSION

In this study, the heavy metal removal efficiency of pea pods, which are used as vegetable waste and have no economic value, was investigated by using them as an adsorbent. As the variables affecting the adsorption process in the Nickel (II) removal determination of waste pea pods; adsorbent dose, pH, and time are optimized. The optimum amount of adsorbent dose was found to be 350 mg, and the optimum duration was found to be 60. In the determination made as a result of pH optimization, it was found that the nickel removal efficiency was 50% when the adsorbent dose was 350 mg, the time was 60 minutes and the pH was original. As a result of the experimental and statistical analyzes, it was concluded that the waste pea pod could be used as a cheap adsorbent. This research has been tried in synthetic wastewater, and it is not known what kind of result will be obtained in real wastewater.

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