Original Article

Removal of Heavy Metals from Industrial Effluents using Burnt Potato Peels as Adsorbent

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ABSTRACT

The presence of heavy metals in water makes water unfit for use and causes various hazardous health problems. This research investigates the physical and chemical properties of the collected industrial effluent samples of different industries and the use of burnt potato peels (BPP) as adsorbents to remove heavy metal ions from industrial effluents. Various parameters such as pH, adsorbent volume, and contact time were investigated. The concentration of heavy metal ions was accurately quantified using complexometric titration and atomic absorption spectroscopic analyses. Various heavy metals such as Co^{+}, Mg^{+}, Fe^{+}, Pb^{+}, and Cd^{+} were found in the samples with varying concentrations. The burnt potato peels showed the maximum adsorption of about 61% at pH 9, 60 min contact time, 0.5 g of burnt potato peels, and 10 mg/L of sample concentration.

Introduction

Industrialization has a huge impact on our environment and is one of the major causes of pollution. The release of heavy metals from industries is one of the serious issues that is adversely affecting the lives of living beings. Everyday a large number of heavy metals are released from various sources such as anthropogenic sources like mining, industrial production, sewage discharge, smelting processes, automobiles, etc. and natural sources like erosion, and volcanic eruptions. Heavy metals act as resistive pollutants, toxic by nature as they cannot be biodegraded and accumulate in water bodies, soils, and even enter the food chain, posing risks to the environment and human well-being [1-6]. Removal of heavy metals can be done using various techniques such as ultrafiltration [7], chemical coagulation [8], flocculation [9], membrane filtration [10], adsorption [11], and ion exchange [12]. Heavy metals are carcinogenic and cause numerous diseases, as displayed in **Figure 1** which may lead to acute failure of various organs [13]. One such method that has garnered attention is using adsorbents for heavy metal removal. Bio-adsorbents are natural or modified materials with a high affinity for binding heavy metals from aqueous solutions. This eco-friendly approach offers several advantages, including low cost, wide availability, and minimal secondary pollution.

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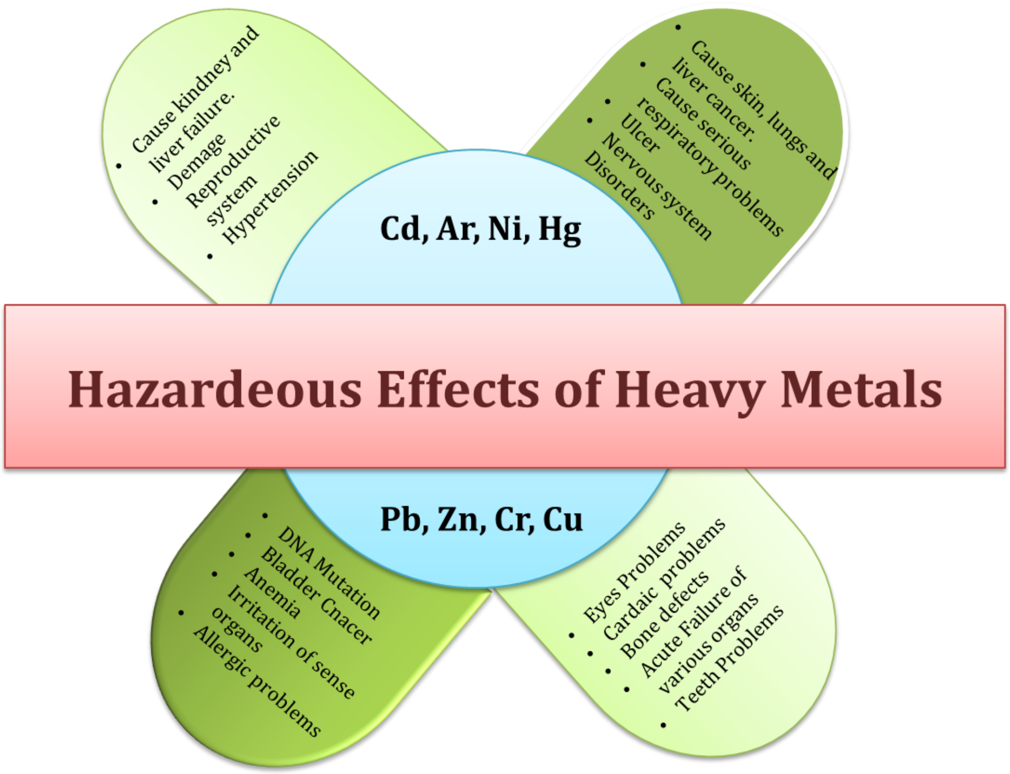

Figure 1. Hazardous effect of heavy metals on human health

Bio-adsorbent such as potato peels show efficient adsorption of heavy metal ions present in water as they have charged functional groups on their surface which interact with the metals and adsorb them on the surface of the bio-adsorbent [14-17]. Adsorption serves as a mechanism in which contaminants are attracted and adhere to the surface of solid materials, known as adsorbents. The process capitalizes on intermolecular forces such as Van der Waals interactions, hydrogen bonding, and electrostatic forces to attract and immobilize heavy metal ions from aqueous solutions. The inherent advantages of adsorption include its operational simplicity, capacity to accommodate diverse metal types, and the potential for adsorbent regeneration and reusability. Consequently, extensive research efforts have been directed towards developing advanced adsorbent materials and optimizing the variables that govern the adsorption process, all aimed at bolstering the efficiency of heavy metal removal [18-21]

This research provides a comprehensive analysis of industrial effluents from the Peshawar Industrial Estate and the detection of heavy metals within these discharges. In addition, it explores the potential of using burnt potato peels as an adsorbent for the removal of heavy metals from contaminated water sources. The growing concerns over the contamination of natural water resources by industrial effluents and the subsequent accumulation of heavy metals necessitate urgent action.

Experimental

Materials and methods

Instruments

The pH of the samples was determined using a Thermo scientific pH meter-ORION STAR A111. For measuring the electrical conductivity of the

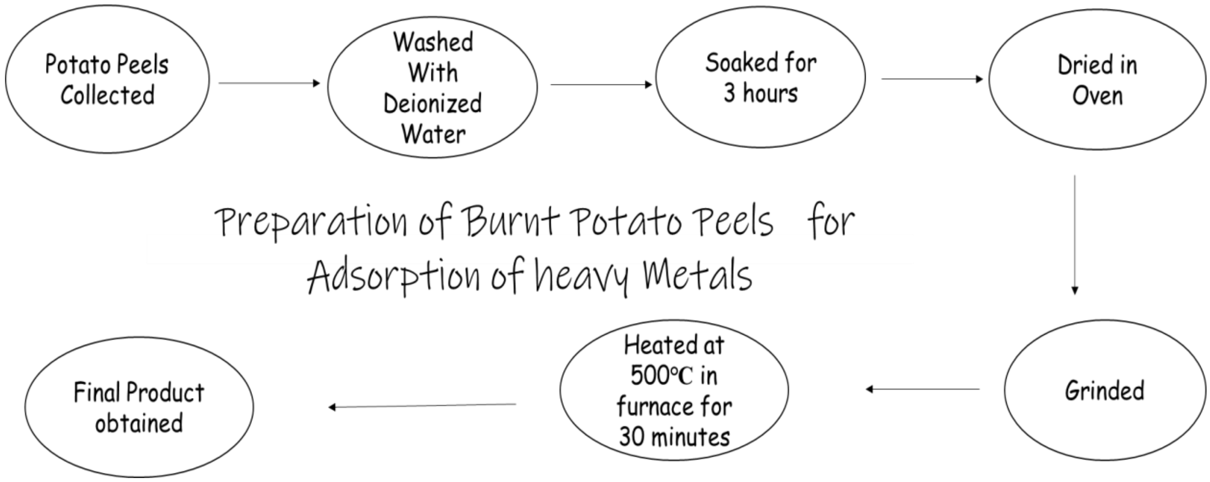

Figure 2. Preparation of burnt potato peels bio-adsorbent

samples conductivity meter-Hanna HI-2211 was used. Turbidity, total suspended solids, and total dissolved solids of the samples were analyzed with the help of colorimeter-DR 900. To detect and find the concentration of heavy metals in the samples atomic adsorption spectrophotometer (AAS 700, Perkin Elmer, USA) was used. The oven (Thermolyne furnace 48000) was used for the drying purpose of potato peels.

Bio-adsorbent preparation

Potatoes peels were collected and washed using di ionized water to remove the dirt and impurities from it. The peels were soaked for 3 hours and then dried in an oven at 100 °C. Dry potato peels were ground using a nonmetallic blade mill and placed in a sealed container inside a desiccator for one day. Subsequently, the potato peels were transferred to a muffle furnace and heated at 500 °C for 30 minutes, resulting in the combustion of potato peels (**Figure 2**).

Samples collection

Industrial effluent samples were collected from the various sites of the industrial area of Hayatabad Peshawar, Pakistan located at the latitude of 33.993 and longitude of 71.424 using grab sampling technique from both high flow and low flow water streams in PET bottles.

Sample analysis

Various chemical and physical parameters of the samples such as pH, electrical conductance, general appearance, temperature, alkalinity, and turbidity were studied. The value of total dissolved solid (TDS) and total suspended solid (TSS) of the samples was also analyzed, as presented in **Table 1.**

Table 1. Analysis of industrial effluent samples

Sample No.	Temperature (˚C)	Electrical conductivity (s/m)	General appearance	Total dissolved solids (mg/L)	Total suspended solids (mg/L)	Turbidity (NTU)	Alkalinity (ppm)	pH
1	23.7	2950	Hazy	1622	24	1.4	260	6.59
2	25.6	2647	Hazy	1809	38	0.8	240	5.1
3	30.4	3180	Hazy	1749	42	1.5	236	6.56

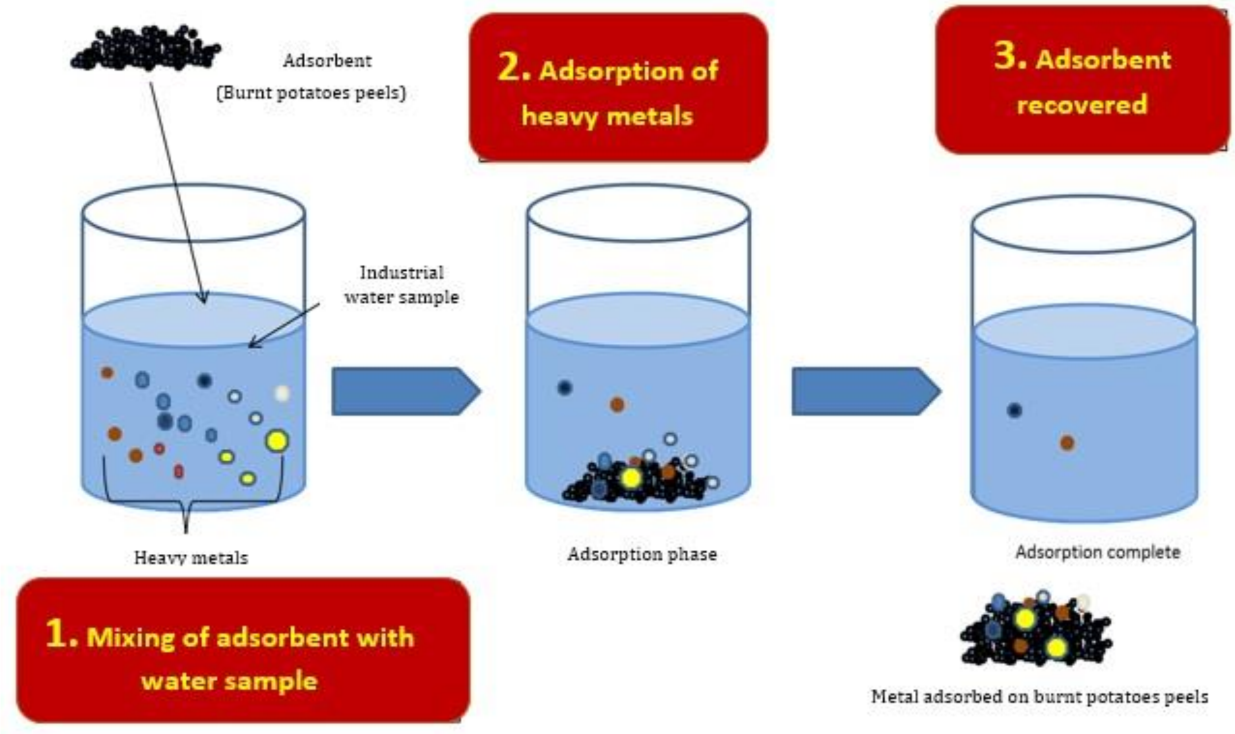

Figure 3. General mechanism of adsorption of heavy metals using burnt potato peels as adsorbent

Adsorption study

Adsorption of metal ions was carried out by mixing all three samples using the batch adsorption technique (**Figure 3**). The study was conducted with different initial pH conditions, adsorbent dosage, and varying contact times. To adjust the solution's pH, 0.1 N solutions of HCl (hydrochloric acid) and NaOH (sodium hydroxide) were used. The metal ions were determined using complexometric titration after passing the solution through Whatman No. 44 filter paper with discarding the first 5 mL fraction of each filtrate.

The metal percent adsorption was calculated using the following equations (**1** & **2**):

$$Q_e = \frac{C_i - C_e}{m} V \quad (1)$$

$$\%Removal = \frac{C_i - C_e}{C_i} \quad (2)$$

Where, C_i represents the initial concentration, C_e is the equilibrium concentration, Q_e is the adsorption capacity, and "m" is the weight of the adsorbent.

Results and Discussion

Physical and chemical properties

The difference in the physical and chemical properties of the samples was observed which may be because samples were collected from three different sites in the industrial state of Hayatabad Peshawar, Pakistan. The pH of the samples was almost near neutral except for one that was acidic because that sample was collected near a beverage industry. As beverage industries release water effluent containing dissolved CO_2 and metal ions its effluents possess acidic pH [22,23]. The cloudiness in the samples was due to the presence of total dissolved solids, total suspended solids, and metal ions in the samples [24,25]. The conductivity of water samples was greater than that of normal because of the presence of metal ions which act as electrolytes [26].

Samples characterization

Atomic adsorption spectroscopy analysis

The presence and quantity of heavy metals in the collected samples were determined using atomic adsorption spectroscopic analysis. It was found that all three samples contain Mg^{+}, Cd^{+}, Fe^{+}, Pb^{+}, and Co^{+} details of which are presented in **Tables 2, 3,** and **4**. The values of ions vary for the samples because of their collections from different sites as they contain effluent from different industries.

Table 2. Atomic adsorption spectroscopic analysis of sample 1

Analyte	Wavelength (nm)	Mean (mg/L)	Standard deviation	% Relative standard deviation
Mg	285.2	4.802	0.1751	3.65
Cd	228.8	0.007	0.0106	153.97
Fe	248.3	0.800	0.1416	17.70
Pb	283.3	0.05	0.096	289.21
Co	240.7	0.030	0.150	73.64

Table 3. Atomic adsorption spectroscopic analysis of sample 2

Analyte	Wavelength (nm)	Mean (mg/L)	Standard deviation	% Relative standard deviation
Mg	285.2	4.811	0.1006	2.09
Cd	228.8	0.013	0.0014	10.86
Fe	248.3	0.414	0.1014	24.49
Pb	283.3	0.21	0.121	56.82
Co	240.7	0.022	0.0098	44.51

Table 4. Atomic adsorption spectroscopic analysis of sample 3

Analyte	Wavelength (nm)	Mean (mg/L)	Standard deviation	% Relative standard deviation
Mg	285.2	4.981	0.0599	1.20
Cd	228.8	0.009	0.0073	78.68
Fe	248.3	0.200	0.0657	32.84
Pb	283.3	0.20	0.150	73.64
Co	240.7	0.009	0.0106	119.14

Effect of pH

The adsorption of metal ions on potato peels at different pH (2-11) was determined using the complexometric titration technique and it was observed that the adoption of the metal ions increases with the increase in pH. The increase in the adsorption with an increase in pH may be due to the reduction of competition between metal ions and hydrogen ions [27-30]. Further increase in pH results in the adsorption reduction because in more basic pH precipitate formation starts and the metal ion starts generating its anionic metal hydroxides which then cannot be adsorbed due to its nature [31,32]. At more acidic pH, the cations are greater in number due to the generation of H^+ ion and the adsorption site for cations becomes hindered. A repulsive force develops between the ions of the same positive charges which results in the adsorption reduction (**Figure 4**) [33].

Effect of contact time

The adsorption of heavy metals was investigated at various contact times, specifically 10, 20, 30, 40, 50, 60, and 70 minutes. Burnt potato peels exhibited the highest level of adsorption after 60 minutes of contact time, under optimal conditions of pH 9, 20 mL of sample, and 0.5 g of adsorbent concentration. An increase in adsorption was observed as the contact time increased up to 60 minutes. Beyond that point, adsorption remained constant with further increases in contact time. This initial increase in adsorption can be attributed to the availability of free and highly unsaturated adsorbent sites at the beginning of the process. With time, these sites

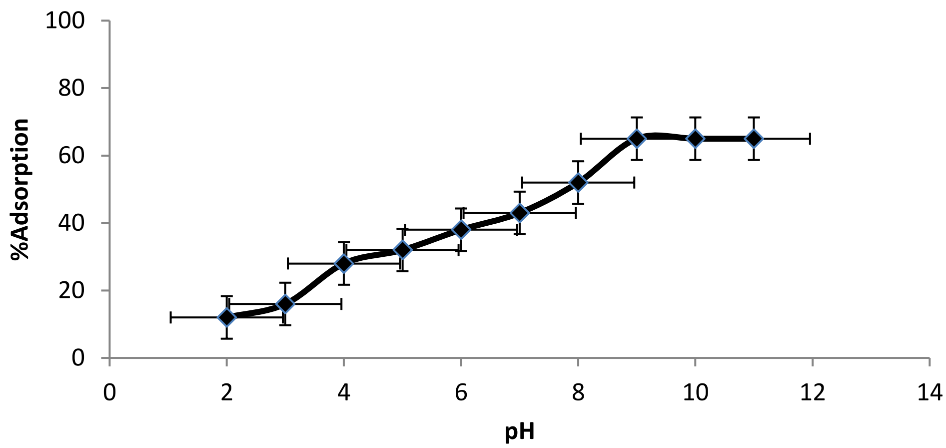

Figure 4. Effect of pH on the adsorption capacity of potato peels

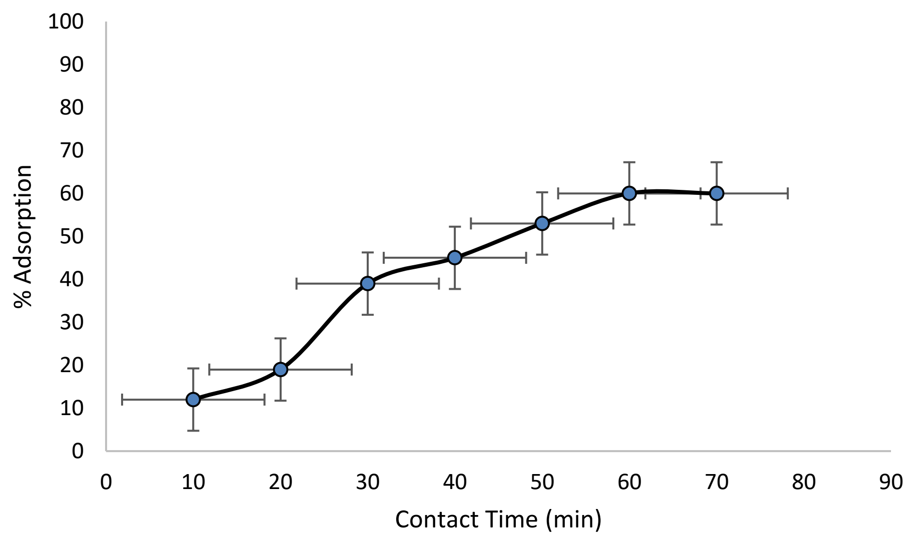

Figure 5. Effect of contact time on adsorption capacity of burnt potato peels

became progressively covered, eventually reaching equilibrium, which explains why the adsorption of metals did not increase further [32,34-36]. The adsorption may decrease if the time of contact is prolonged because with greater contact time adsorbent reaches its maximum efficiency for adsorption and the desorption process gets started (**Figure 5**) [37, 38].

Effect of adsorbent dosage

Adsorption of heavy metals was determined with varied initial adsorbent dosages between 0.1 g to 2 g under optimum conditions of pH. It was determined that by increasing the initial dosage of the adsorbent an increase in adsorption occurred. The fact is that increasing the adsorbent dosage results in an expanded surface area and a higher number of active sites for adsorption, which leads to an increase in the adsorption of heavy metals. The adsorption percentage decreases with a further increase in adsorbent dosage because the adsorbate-adsorbent duo reaches equilibrium and the adsorption sites become hindered. The decrease may also be due to the fact that an increase in the length of diffusion path occurs due to the overlapping or clustering of adsorption sites (**Figure 6**) [37,39-42].

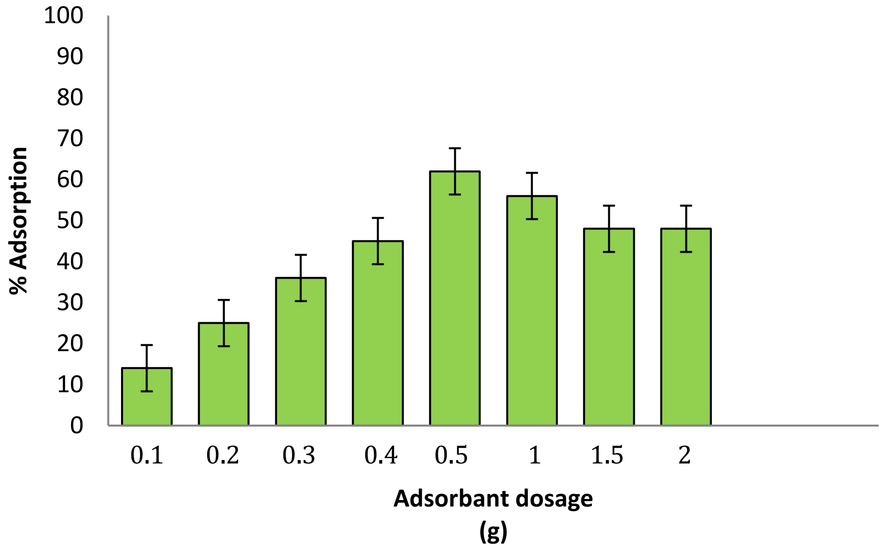

Figure 6. Effect of initial adsorbent concentration on adsorption of heavy metals

Conclusion

Analysis of various physical and chemical parameters of industrial effluent samples collected from various sites of the industrial state Hayatabad, Peshawar, Pakistan was carried out. The sample was characterized using the atomic adsorption spectroscopy technique for detecting heavy metals in it. Heavy metals such as Co^{+}, Mg^{+}, Fe^{+}, Pb^{+}, and Cd^{+} were detected in the samples, and their removal was carried out. Batch adsorption technique was used for the removal of heavy metals from the samples using burnt potato peels as adsorbent. The removal of heavy metals was determined using the complexometric titration technique. It was determined that burnt potato peels can act as an efficient adsorbent as it showed an adsorption efficiency of 61% under optimum conditions of pH, adsorbent dosage, contact time, and solution concentration.

Future Recommendation

Potato peels are an environmentally friendly efficient adsorbent and can be used for the adsorption of heavy metals on a larger scale. Therefore, its use as an adsorbent for the removal of heavy metals is highly recommended. However further study is recommended on potato peels as an adsorbent for the removal of other pollutants such as dyes and pesticides from waste water.

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Disclosure Statement

No potential conflict of interest was reported by the authors.

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