Removal of Heavy Metals from Water in the Presence of Organic Wastes: Fruit Peels

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Abstract**—**In this experiment our goal was to remove heavy metals from water. Generally, removing toxic heavy elements: Cu^{+2}, Cr^{+6} and Fe^{+3}, ions from their aqueous solutions has been determined with different kinds of plants' peels. However, this study focuses on banana, peach, orange, and potato peels. The first step of the experiment was to wash the peels with distilled water and then dry the peels in an oven for 80 h at 80 °C. The peels were washed with NaOH and dried again at 80 °C for 2 days. Once the peels were washed and dried, 0.4 grams were weighed and added to a 200 mL sample of 0.1% heavy metal solution by mass. The mixing process was done via a magnetic stirrer. A sample of each was taken at 15-minute intervals and the level of absorbance change of the solutions was detected using a UV-Vis Spectrophotometer. Among the used waste products, orange showed the best results, followed by banana peel as the most efficient for our purposes. Moreover, the amount of fruit peel, pH values of the initial heavy metal solution, and initial concentration of heavy metal solutions were investigated to determine the effectiveness of fruit peels for absorbency.

Keywords**—**Absorbance, heavy metal, removal of heavy metals, fruit peels.

I. Introduction

THE purpose of the experiment was to remove heavy metals from water due to their harmful nature for both health and the environment. The term heavy metal is used for toxic metal elements that have high densities (mostly above 5 g/cm^3) and are capable of harm. The reason why heavy metals are toxic for the human body is due to their chemical reactivity. Heavy metals tend to react with cellular structural proteins, enzymes and membrane systems causing malfunctions and structural damage to the cellular system/structure [1]. Environmentally, heavy metals have the potential to contaminate water and soil, posing a toxic threat. Once they are mixed into these environments, their removal or extraction becomes challenging. This study aimed to investigate the removal of three specific heavy metals, namely Fe, Cr, and Cu, from water.

Iron in water can serve as a carrier for bacteria, posing potential harm. However, iron overload can present a more serious issue. Excessive levels of iron in the body can result in iron overload, which occurs due to a mutation affecting iron absorption. Apart from internal complications, iron can also have adverse effects on the skin, such as damaging healthy skin cells and contributing to the development of wrinkles on the epidermis. Most skin problems associated with iron are often attributed to bathing in water with a high iron concentration. This can lead to the blocking of skin pores, resulting in the accumulation of oils, as well as the onset of acne or eczema [2]. Chromium can have similar effects to iron when it comes into contact with the skin. However, unlike iron, chromium can cause the opening of wounds instead of blocking pores. Individuals, especially workers, who have been exposed to chromium on the skin have reported experiencing chronic ulcers and irritative dermatitis. The International Agency for Research on Cancer has documented cases of sinonasal cancer associated with chromium exposure. People who have come into contact with chromium, particularly workers, have also reported instances of rhinitis, bronchospasm, and pneumonia [3].

Copper compared to the rest of the heavy metals has more internal problems. Most frequent cases of copper exposure (in high dosages) are liver damage, abdominal pain, cramps, nausea, diarrhea and vomiting [4].

According to previous studies, iron can be harmful to plants and soil at around 5 ppm to 200 ppm (parts per million). Even though the elemental form is harmful, iron compounds can have a more abundant impact on the environment [5].

The environmental harms caused by chromium are extensive, particularly in relation to plants. Chromium (Cr) affects pigment synthesis in plants by degrading aminolevulinic dehydratase, an essential enzyme in chlorophyll synthesis. The lack of chlorophyll results in plant malnutrition, leading to reduced growth and development. Additionally, a high concentration of Cr in water can contaminate nearby crops, potentially entering the bodies of consumers [6].

In previous studies, natural materials such as avocado, Hami melon, and dragon fruit peels were chosen as renewable adsorbents for water purification [8] Another study was conducted to investigate the use of grapefruit peels (*Citrus paradisi*) for the removal of lead, copper, and zinc from industrial wastewater [9]. Moreover, various fruit and vegetable peels have been explored and discussed in reviews, such as pineapple peels, potato peels, citrus fruit peels (orange peels, lemon peels), pomegranate peels, banana peels, tomato peels, and more [10]. Other publications have also investigated the use of peels from fruits like mango, passion fruit, coconut, avocado, apple, lulo, and tangerine [11].

II. Method

A. Materials

The heavy metal-containing solutions were prepared using iron(III) chloride (Merck), potassium dichromate (Merck), and

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copper(II) sulfate (Merck). Different fruit or vegetable waste peels, including peach, potato, banana, and orange, were used in the experiments. Prior to use, all waste peels underwent purification steps. They were washed and stirred with distilled water for 8 hours, followed by washing with NaOH. The peels were then dried in an oven at 80°C for 2 days.

B. Experimental Processes

All experiments were conducted at room temperature. The primary objective of the study was to investigate the effects of various peels on the removal of heavy metals from water sources. To achieve this, three identical solutions containing 0.1% Fe/Cu/Cr by mass were prepared and mixed with 0.4 g of dried peels. During the experiments, the solutions were stirred magnetically to promote the equilibrium of adsorption processes.

During the experiment, 10 mL aliquots were collected from the flask outlet at 15-minute intervals, starting from 0 minutes and continuing until 90 minutes. These aliquots were then filtered through a Millipore filter (0.45 μm) to remove the peels from the solution. Subsequently, the filtered samples were analyzed using an Ultraviolet-Visible Spectrophotometer to measure the characteristic absorption peaks at 294 nm, 800 nm, and 411 nm at 0, 30, 45, 60, 75, and 90 minutes, respectively.

The experimental procedures were repeated using the natural pH of the heavy metal solutions, which was measured to be pH 6.4. This pH value was maintained throughout all the heavy metal removal and decolorization experiment.

To calculate the metal adsorption amounts of each peel type, the calibration curve of solutions was graphed. Then, (1) was used to calculate the amount of metal adsorbed onto the peels:

$$qe(mg/g) = \frac{(c-ci)}{m}V \quad (1)$$

where, C is the initial concentration of the solution (mg/L), C_i is the metal ion concentration after the peel was allowed to adsorb the metals for 30 min (mg/L), V is the volume of the metal solution (L) and m is the mass of the peel (g).

Later on, the decolorization rate of the solution by the peels was calculated by using (2):

$$Decolourization\ rate\ (\%) = \frac{(ci-co)}{ci}x100 \quad (2)$$

where, C_i is the concentration of the metal solution after being stirred for 30 min (mg/L), C_o is the equilibrium metal concentration after the peel was allowed to decolorize the dyes for 45-90 min (mg/L).

C. Adsorption Parameters

The effect of initial metal solution concentration on the decolorization was examined by changing the concentration of the metal solutions to 0.1% to 0.4% by mass. The same adsorption process was used. Equation (2) was used to calculate the decolorization rate.

The effect of peel amount was examined by changing the peel amount to 0.1 g to 0.6 g.

Optimum values were obtained from the various experiments, with the concentration of the metal solution set at 0.1% by mass and using 0.4g of dried peels at room temperature and at a natural pH value.

III. Results

A. Decolorization Process

Decolorization activities of peels were investigated under room conditions at natural pH. According to the results, the highest adsorption of heavy metals was observed in the presence of orange peel after 75 minutes, as indicated in Tables I-III. This can be attributed to the direct relationship between absorbance and concentration. Furthermore, Table IV displays the decolorization rates of each metal solution using different peels.

TABLE I
Absorbance Change in Fe+3 Containing Solution in the Presence of Selected Peels during a 90-Minute Time Period

Type of peel	Time (min)					
	Initial	30 min	45 min	60 min	75 min	90 min
Orange	2.673	2.681	2.566	2.390	2.178	2.009
Banana	2.673	2.615	2.509	2.461	2.372	2.245
Peach	2.673	2.660	2.505	2.488	2.490	2.487
Potato	2.673	2.667	2.589	2.401	2.406	2.399

TABLE II
Absorbance Change in %0.1 Cu+2 Containing Solution in the Presence of Selected Peels during a 90-Minute Time Period

Type of peel	Time (min)					
	Initial	30 min	45 min	60 min	75 min	90 min
Orange	4.620	4.562	4.271	4.063	3.798	3.501
Banana	4.620	4.568	4.274	4.111	3.895	3.730
Peach	4.620	4.590	4.592	4.867	4.872	4.875
Potato	4.620	4.522	4.388	4.314	4.271	4.167

TABLE III
Absorbance Change in %0.1 Cr+6 Containing Solution in the Presence of Selected Peels during a 90-Minute Time Period

Type of peel	Time (min)					
	Initial	30 min	45 min	60 min	75 min	90 min
Orange	4.574	4.529	4.403	3.991	3.844	3.765
Banana	4.574	4.530	4.493	3.801	3.976	3.834
Peach	4.574	4.560	4.411	3.888	4.480	4.507
Potato	4.574	4.534	4.499	3.928	3.946	3.861

TABLE IV
Decolorization Rate Values of Each Metal Solution after Treatment with Peels

Name of Peel	Rate (Fe) (mg/L.sec)	Rate (Cr) (mg/L.sec)	Rate (Cu) (mg/L.sec)
Orange	0.011	0.013	0.018
Banana	0.0062	0.012	0.014
Peach	0.0029	0.00088	cannot be found
Potato	0.0055	0.011	0.0060

1. Adsorption Experiments

Activities of peels were investigated under room condition at natural pH for the removal of metals. As can be seen from Fig. 1, orange peel was able to decolorize all the targeted metal solutions due to its highest absorbance capacity among other peels. Removal capacity of orange peel was slightly the same in Fe^{+3} and Cr^{+6} containing solutions. Moreover, orange peels were much more effective under room conditions at natural pH when the peel amount is selected as 0.4 g. Furthermore, the highest efficiency was observed in the presence of orange peels after 45 min. This was followed by banana peels. Fig. 2 shows the adsorption rate comparison of each peel in different targeted metal solutions.

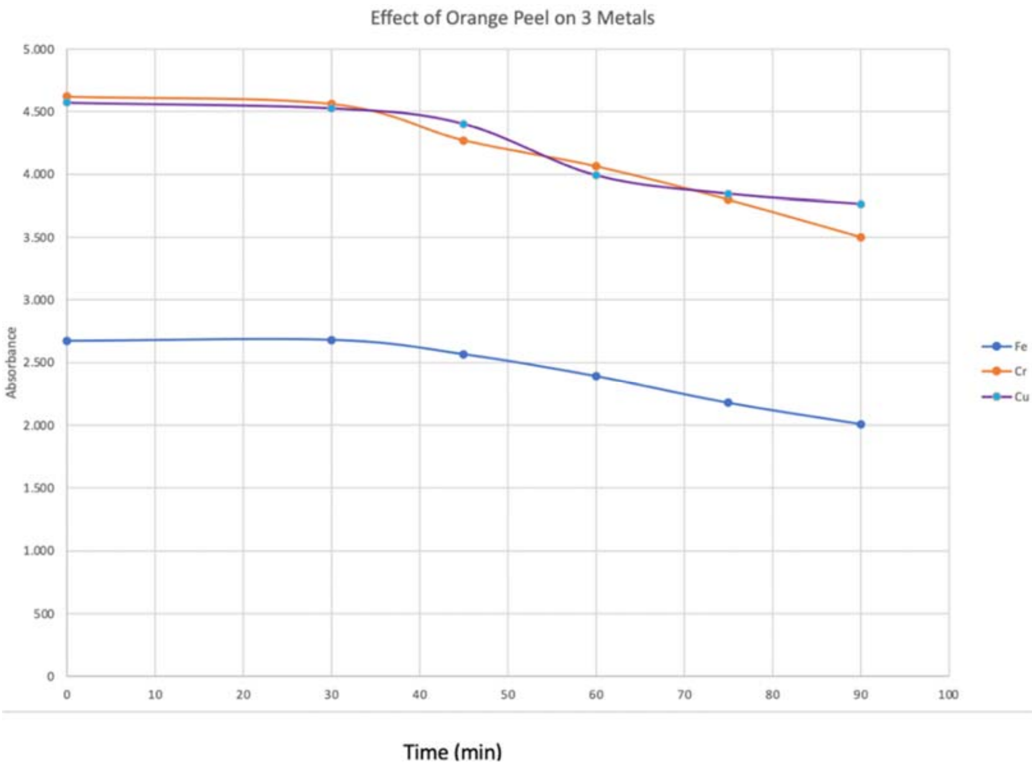

Fig. 1 Effect of Orange Peel on Three Targeted Metal Solutions

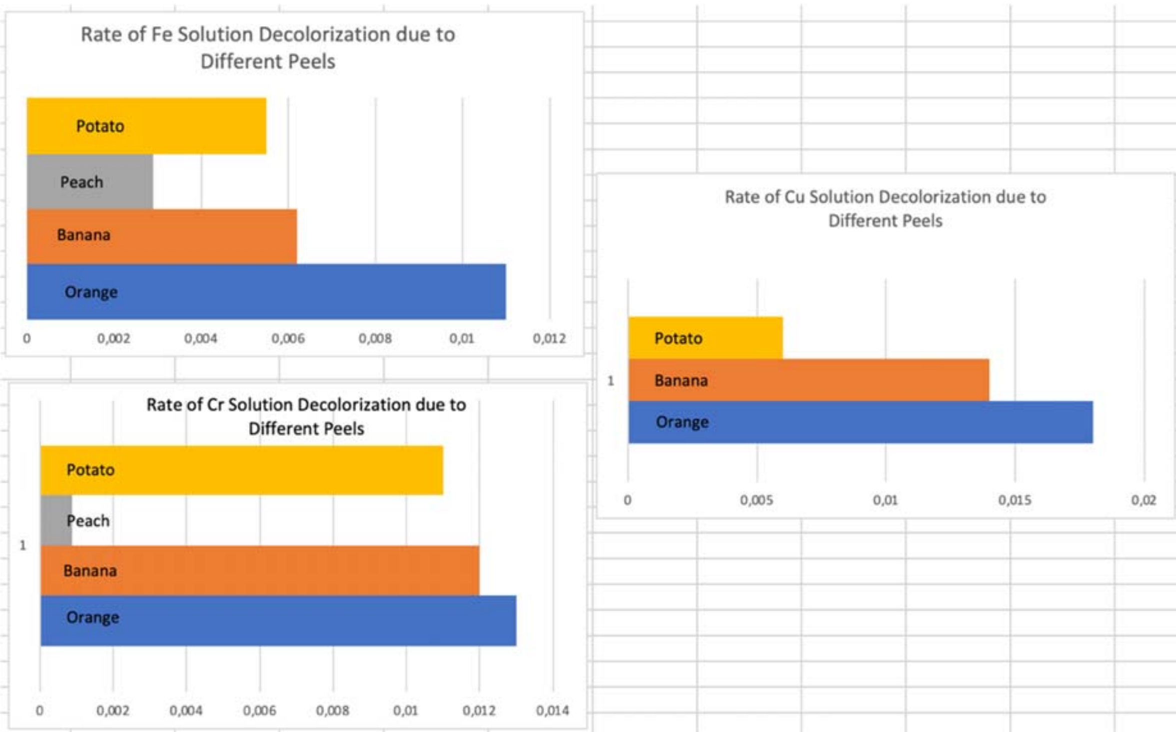

Fig. 2 Decolorization Rate Comparison of Different Peels

2. Effect of pH

The pH of the aqueous medium was studied at three pH values: 4, natural pH, and 9, to understand its effects on the decolorization of metal solutions in the presence of orange peel. The maximum adsorption was observed at the natural pH, which can be attributed to the charge of the peel surface. At the natural pH value, the peel surface is negatively charged. The electrostatic attractions between positively charged metal ions and the negatively charged peel surface facilitate the adsorption process.

3. Effect of Concentration

The adsorption rate of metal solutions at concentrations of 0.1%, 0.2%, and 0.4% was examined using different peels. The experiments were conducted at the original pH values of the solutions. It was observed that the adsorption rate increases at lower metal ion concentrations. This can be attributed to the fact that at lower concentrations, there are fewer metal ions compared to the available surface area of the peels. As a result, the adsorption and decolorization processes occur more rapidly.

4. Effect of Peel Amount

To determine the optimal amount of peels, the mass of the peels was varied from 0.1 g to 0.6 g. It was observed that increasing the amount of peels led to an increase in the decolorization rate up to a certain mass value. The highest decolorization rate was observed when 0.4 g of peel was used. This can be attributed to the increased number of active sites on the peels, which facilitated the decolorization process.

IV. Conclusion

The findings of this study indicate that various fruit and vegetable peels, particularly orange peels, are highly effective in removing heavy metals from water sources. These absorbent peels offer a cost-effective solution for heavy metal removal. Orange peels demonstrated the highest efficiency in removing targeted metals such as iron, chromium, and copper. Banana peels also showed good effectiveness, while peach peels were found to be the least effective in this study. The removal efficiency of orange peels ranged from 16.87% to 25.07% at a metal concentration of 0.1% by mass and a pH of 6.4. These results highlight the potential for further research and the development of economically feasible systems for large-scale water treatment using absorbent peels. The availability of these absorbents and their generation through alkali treatment make them suitable for the removal of heavy metals from water and wastewater resources.

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