



Lead removal from wastewater by Orange peel adsorbent

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ABSTRACT

In this paper, Lead removal has been studied using Orange peel OP as an adsorbent. In addition, the effect of operating parameters including pH, contact time, and the concentration of lead on adsorption rate have been examined. Orange peel powder OP has demonstrated significant potential as an eco-friendly and efficient material for Lead removal from wastewater. Under the optimum conditions, maintaining a pH of 5, and providing a contact time of 6 hours, Lead removal efficiency exceeding 70% were achieved by using 4 grams of OP. These findings underscore the viability of OP as a sustainable solution for wastewater treatment, particularly for applications involving moderate Lead contamination levels.

Keywords: Lead, Orange peel, Adsorption, Natural adsorbent, pH, Contact time, Feed concentration.

1. INTRODUCTION

Heavy metals have a significant impact on the environment due to water contamination. The release of heavy metals into water bodies has been accelerated by rapid industrial development [1].

The high toxicity of Lead in natural water or wastewater is a cause for concern due to its impact on aquatic life, the environment, water quality, and consumption. Lead build-up in the food chain can result in various human illnesses, such as cancer, anemia, paralysis, and Lead poisoning. Lead discharge into the environment is a result of many industries, such as battery, dye and pigment, plastic, steel, electronic, and pesticides. Wastewater that has Lead contamination must be treated below water quality standards before being released for a safer environment [2].

Steel production, mining, electroplating, transformation coating, solder plates, and etching are some of the industries that discharge potentially toxic trace metals into the natural environment [5].

Heavy metals like cadmium, arsenic, cobalt, chromium, copper, Lead, and zinc are present in polluted waters [6].

Usually, materials such as activated carbon are used to remove different pollutants from water. Due to the high cost of these materials, it is necessary to find new, low-cost, biodegradable eco-materials to use for the removal of heavy metals from polluted waters [6]. For example, Leandro S. Queiroz et al. explored an innovative approach to tackling water pollution by using acai seed waste to create activated carbon for removing metal ions like Lead (Pb^{2+}), iron (Fe^{2+}), and magnesium (Mg^{2+}) from water. By employing potassium hydroxide (KOH) in two different ratios and further enhancing the material with nitric acid treatment under microwave irradiation, the researchers developed activated carbons with exceptional properties. These materials showed impressive surface areas (1462–2774 m²/g) and were enriched with functional groups that improved their adsorption capabilities and resulted in successfully removing 86% of Lead, 69% of iron, and 8% of magnesium within just one hour. This efficiency surpassed that of commercial activated carbon, showcasing the promise of acai seed-derived carbon as a cost-effective and environmentally friendly solution for heavy metal removal from water. The results suggest that such modified carbons could offer a sustainable alternative for addressing water contamination issues [7].

A number of adsorbents including olive cake, bone meal-derived apatite, fish scale, tea-industry waste, Orange peel, banana peel, pomegranate, and corn cob have been reported for their capability to eliminate heavy metals from waste water because they include a variety of functional groups. Due to their simplicity, availability, low production costs, and non-generation of secondary pollutants, the use of these waste agricultural by-products has recently gained great momentum [4].

Orange peels are a promising natural adsorbent due to their rich composition of cellulose, hemicellulose, lignin, and pectin. These components, along with functional groups like hydroxyl (-OH) and carboxyl (-COOH), help bind heavy



metals like lead from wastewater. However, the raw peel's smooth and non-porous surface limits its adsorption capacity, meaning modifications are needed for industrial applications with high lead concentrations. Despite this, Orange peels are widely recognized as an agroindustrial waste material with strong adsorptive properties. Their effectiveness in wastewater treatment comes from their high surface area and functional groups, which influence their biosorption capacity based on acidity or basicity [3].

As mentioned before, due the presence of cellulose, hemicellulose, lignin, and pectin Orange peel facilitates the adsorption process and can serve as an effective biosorbent. Thus, natural Orange peel as an adsorbent has been used in this study and the effect of pH, contact time, and feed concentration on the adsorption of Lead have been examined.

2. MATERIALS AND METHODS

All chemicals were of analytical grade and were used as received without further purification.

In this study, synthetic Lead solutions with varying concentrations (10 to 70 mg/L) were prepared to evaluate Lead removal efficiency. The experiments were conducted under controlled conditions at defined pH to ensure consistency and accuracy in the results. $\text{Pb}(\text{NO}_3)_2$ purchase from Merck company.

To prepare Orange Peel Powder OP, fresh Orange peels were thoroughly washed with tap water to remove any dirt and impurities. A measured 50 grams of the cleaned peels were then soaked in a 95% Ethanol and 0.5 M NaOH solution (2:1 ratio) for 12 hours to enhance their adsorption properties. (Ethanol and NaOH purchase from Merck company). After soaking, the peels were rinsed with distilled water until the pH of the rinse water reached neutrality. The treated peels were then dried in a hot air oven at 90°C for 5 hours. The resulting Orange peel powder was stored in a moisture-free container until further use. The studied parameters in this paper are feed pH (The pH of each solution was adjusted to a defined value in range of 1 to 11 to maintain controlled experimental conditions), contact time (1-6 hours), and Lead concentration (solutions containing 10 to 70 mg/L of lead were prepared using lead nitrate $\text{Pb}(\text{NO}_3)_2$). All of the experiments were conducted with fixed dose of OP(4g).

The concentration of Lead in the solution was measured before and after treatment using an Atomic Absorption Spectrophotometer (AAS). The removal efficiency was calculated using the formula:

$$\text{Removal Efficiency (\%)} = \frac{C_0 - C_e}{C_0} \times 100 \quad (1)$$

Where:

C_0 : Initial Lead concentration (mg/L)

C_e : Final Lead concentration after treatment (mg/L).

3. RESULT AND DISCUSSION

3.1 Effect of pH

The pH level of a solution has a major impact on how effectively Lead can be removed. Figure1 presents the effect of pH on Lead adsorption by Orange peel. This is because, in highly acidic conditions, hydrogen ions (H^+) aggressively compete with Lead ions (Pb^{2+}) for the available adsorption sites. As the pH increases, the efficiency steadily improves, reaching its peak of 70% at pH = 5. This happens because the adsorbent surface becomes less crowded with positive charges, allowing Lead ions to bind more easily. However, when the pH goes above 5, the efficiency starts to decline. By pH = 11, it drops below 60%. This reduction occurs because, at high pH, Lead ions start to form solid compounds like Lead hydroxide ($\text{Pb}(\text{OH})_2$), which can no longer be adsorbed effectively. To achieve the best results, maintaining the pH around 5 is critical. At this level, the adsorption process works at its peak, efficiently capturing Lead ions without interference from competing ions or precipitation. This balance makes pH = 5 an ideal condition for wastewater treatment processes involving Lead removal [8,4].

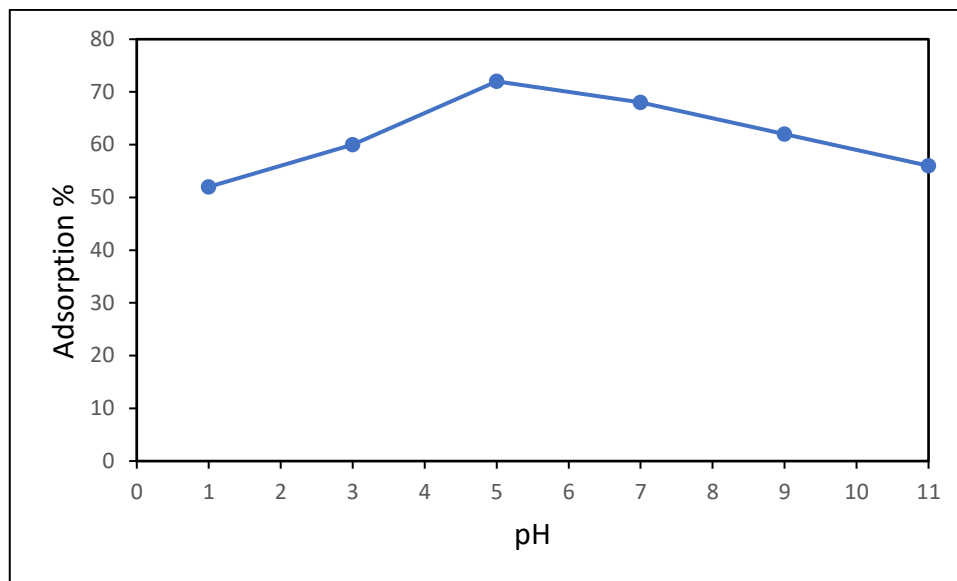


Fig. 1. The effect of pH on Lead adsorption by Orange peel (mixing speed= 200 rpm)

3.2 Effect of contact time

The time that Lead ions are allowed to interact with the adsorbent also affects how much Lead gets removed. According to Figure2, after just 1 hour, the removal efficiency is about 60%, which shows that the adsorption process starts quickly. Over time, the efficiency improves, reaching 65% at 4 hours and about 70% at 6 hours. After 6 hours, the graph flattens, meaning most of the adsorption sites are filled, and further improvement becomes negligible. The optimal contact time is 6 hours. This ensures maximum adsorption without unnecessary delays. Extending the time further adds little value and may not justify the cost or time investment. For practical applications, focusing on this contact time balances efficiency and operational productivity [8,3].

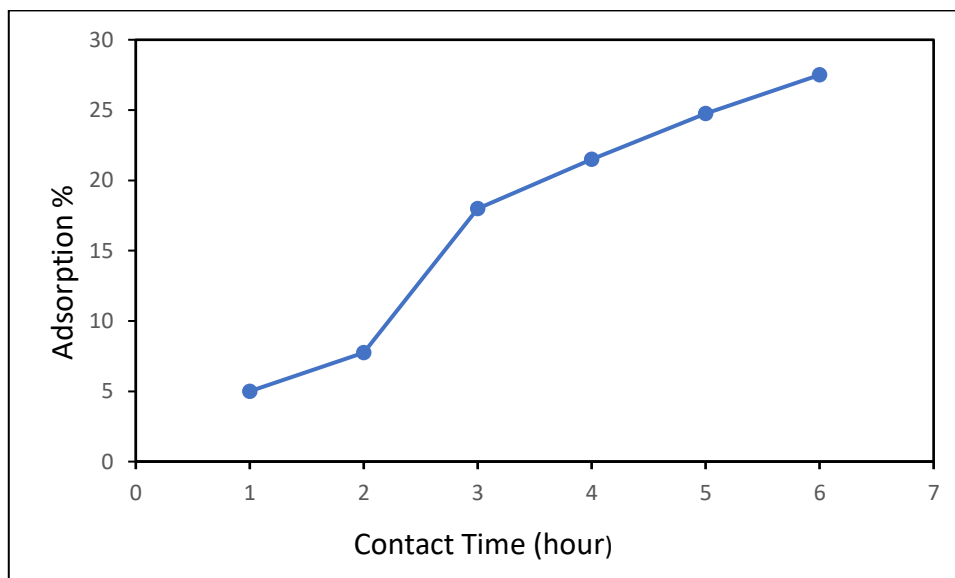


Fig. 2. The effect of Contact Time (hour) on Lead adsorption by Orange Peel (mixing speed= 200 rpm)



3.3 Effect of feed concentration

The concentration of Lead in the wastewater directly affects how well it can be removed. As can be seen, at an initial concentration of 10 mg/L, the removal efficiency is about 70%, as the adsorbent has plenty of available sites to capture the Lead ions. As the concentration increases to 40 mg/L, the efficiency drops to 65%, showing that some adsorption sites are starting to saturate. At the highest concentration of 70 mg/L, the efficiency falls further to just 50%, indicating that the adsorbent's capacity is nearly exhausted [8].

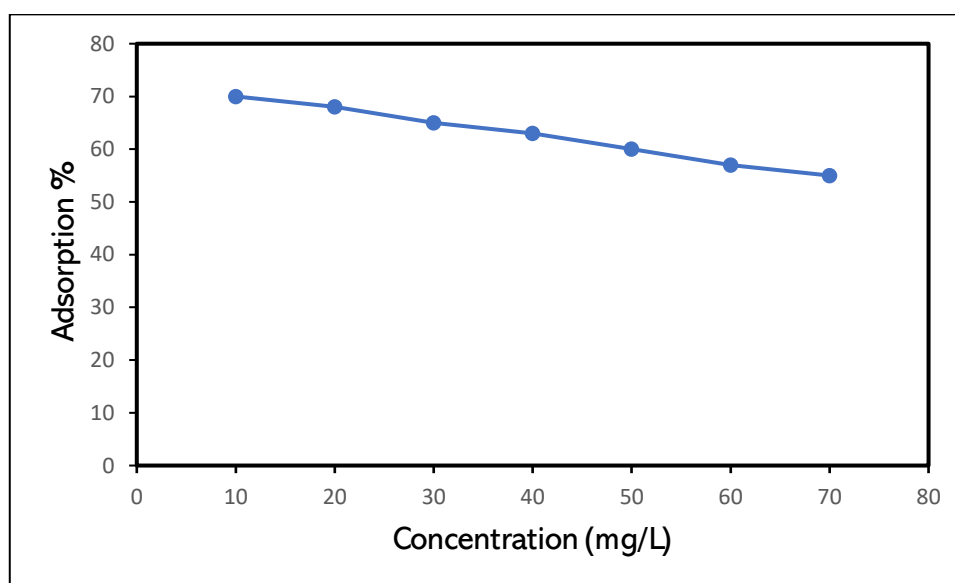


Fig.3. The effect of Concentration on Lead adsorption by Orange peel (mixing speed= 200 rpm)

4. CONCLUSION

Based on the results, Orange peel powder OP proved to be an effective and sustainable material for removing Lead from wastewater. optimizing the conditions, such as maintaining a pH of 5, and allowing 6 hours of contact time, efficiencies of over 70% were achieved by using 4 grams of OP. These results highlight OP's potential as an eco-friendly solution for wastewater treatment, especially for systems dealing with moderate levels of Lead contamination.

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