Green and Cost-Effective Cr (VI) Removal from Industrial Wastewater with Pomegranate Peel Activated Carbon

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Abstract:
This research explores an eco-friendly solution to combat the contamination of water bodies with toxic hexavalent chromium, Cr (VI), often originating from industrial effluents. The study introduces activated carbon derived from pomegranate peels as an effective and low-cost adsorbent for removing Cr (VI) from aqueous solutions and industrial wastewater. The adsorbent demonstrates removal efficiencies of over 70%, particularly at pH 2, offering a sustainable approach to mitigate heavy metal pollution. This eco-friendly method, utilizing readily available pomegranate peels, holds promise for addressing the critical issue of heavy metal pollution in water bodies.

Keywords: Cr (VI) Removal, Industrial Wastewater, Pomegranate Peel Activated Carbon, Green and Cost-Effective.

1. Introduction:

The problem of chromium pollution has escalated, with a particular spotlight on hexavalent chromium, Cr(VI), a highly toxic and carcinogenic variant of the element. Its presence in industrial effluents has raised alarming concerns due to its adverse effects on both the environment and human health. As a result, the quest for sustainable, effective methods to remove Cr(VI) has gained significant attention.

This research paper introduces a novel approach to combat Cr(VI) pollution in industrial effluents. It delves into the use of activated carbon derived from a readily available, often underestimated source: pomegranate peels.

The choice of pomegranate peels for producing activated carbon is underpinned by several advantages. These peels are locally abundant and easily manageable, streamlining the production process. Furthermore, the resulting adsorbent displays remarkable adsorption capabilities, making it a sustainable and budget-friendly option for Cr(VI) removal. This research probes the impact of various factors, such as pH, adsorbent dosage, and agitation time, on removal efficiency, providing valuable insights into an environmentally friendly and efficient method for mitigating Cr(VI) pollution in industrial wastewater

Chromium, a heavy metal, has drawn significant attention in the field of water and wastewater treatment due to its hazardous nature, attributed to its carcinogenic properties [Ahalya *et; al.*, 2001].

Chromium is categorized as one of the 16 toxic pollutants, presenting serious health concerns owing to its carcinogenic and teratogenic effects [Torresday *et;al.*, 2000]. This heavy metal finds its way into the environment through various industrial processes such as electroplating, leather tanning, metal finishing, and inorganic chemical production [Gao *et;al*., 2007]. It's worth noting that Cr (III) is less toxic than Cr (VI) [Ody, 1956].

Conventional methods employed for Cr(VI) ion removal from industrial wastewater include chemical precipitation [Ozer *et;al.*, 1997], reduction [Kim *et;al.*, 2002], reverse osmosis [Padilla and Tavani, 1999], ion exchange membrane processes, and electro dialysis [Verma *et;al*., 2006, Mangale S. 2012]. However, these methods are often economically inefficient and have several disadvantages, such as incomplete metal removal, high reagent and energy requirements, and the generation of toxic sludge or waste by products that require proper disposal. In contrast, adsorption techniques are promising for heavy metal removal due to their efficiency and cost-effectiveness.

Efficiently removing various heavy metals from solutions can be achieved using natural adsorbents, which are not only cost-effective but also eco-friendly. These adsorbents encompass a wide range of materials, including agricultural waste like sunflower stalks, eucalyptus bark [Sarin and Pant, 2005], maize bran [Ramos et;al., 1995], coconut shells, waste tea, rice straw, tree leaves, and peanut shells.

2. Materials and Methods:

2.1 Preparation of Biomaterial as Adsorbent:-

a) Activated Carbon prepared from Pomegranate Peels:

Pomegranate peels was collected. It is washed with distilled water then cut into small pieces dried. It was dried in oven or sun dried at constant weight. After drying the peels were crushed ad sieved to select proper adsorbent grain size. Then, activated carbon prepared by using concentrated sulphuric acids.

2.2 Preparation of Hexavalent Chromium Solution:-

A hexavalent chromium solution was prepared by dissolving K2Cr2O7 in metal-free, doubly distilled water. The concentrations were measured in milligrams per milliliter, making 1 ml equivalent to 100 mg of Cr (VI). Adjustments to the solution's pH were made using 2N H2SO4.

2.3 Adsorption Studies

Adsorption is a surface phenomenon where gas or liquid molecules adhere to the surface of a solid adsorbent. The rate of adsorption depends on factors such as liquid concentration, adsorbent surface area, pore volume, pH of the solution, and chemical nature of the adsorbent. Biomaterials were examined for their batch adsorption capabilities.

This study aimed to remove Cr(VI) from aqueous solutions and electroplating industrial effluents. Various parameters were examined, including the initial concentration of Cr(VI) solution, pH, adsorbent dosage, and agitation time.

2.4 Effect of Initial Concentration:

Different concentrations of Cr(VI) solution (ranging from 0.04 to 0.8 mg) were prepared. A 0.04 ml Cr(VI) solution was diluted to 100 ml in a volumetric flask and marked with distilled water.In 250 ml conical flasks, 100 mg and 1 gm of adsorbent were added.The pH was maintained at 6.3.The sample was agitated for 180 minutes at 150 rpm.After agitation, the sample was filtered using Whatman filter paper No.2, and the filtrate was collected for analysis using Atomic Absorption Spectroscopy (AAS).

2.5 Effect of pH on Cr(VI) Removal:

A 0.1 mg and 1 ml Cr(VI) solution was diluted to 100 ml in a volumetric flask. In 250 ml conical flasks, 50 mg and 500 mg of adsorbent were added. Different pH values (ranging from 2 to 9) were maintained for each sample. The sample was agitated for 90 minutes at 150 rpm.After agitation, the sample was filtered using Whatman filter paper No.2, and the filtrate was collected for AAS analysis.

2.6 Effect of Adsorbent Dosage:

A 0.1 ml and 1 ml of Cr(VI) solution was diluted to 100 ml in a volumetric flask. In 250 ml conical flasks, varying adsorbent dosages (ranging from 10 to 60) were added to samples with the same Cr(VI) concentration. The pH was adjusted to 2 for all samples. The sample was agitated for 120 minutes. After agitation, the sample was filtered through Whatman filter paper No.42, and the filtrate was collected for AAS analysis.

2.7 Effect of Agitation Time

A 0.1 ml and 1 ml of Cr(VI) solution were diluted to 100 ml in a volumetric flask. In 250 ml conical flasks, 50 mg and 1 gm of adsorbent were added. The pH was set at 2, and adsorbent dosages were 50 mg. The sample underwent agitation for varying times (from 10 to 60 minutes). After agitation, the sample was filtered through Whatman filter paper No.42, and the filtrate was collected for AAS analysis.

3. Result and Discussion:

Table No. 1: Initial concentration of Cr(VI) in aqueous solution

Sr. No.	Initial Concentration ml	Concentration of Cr(VI)
1	0.04	4 mg/lit
2	0.06	6
3	0.08	8
4	0.1	10

Table 2 : Initial concentration of Cr(VI) in effluent electroplating industry.

Sr. No.	Initial Concentration ml	Concentration of Cr(VI)
1	0.02	8.602
2	0.04	17.204
3	0.06	25.806
4	0.8	34.408
5	1	43.010

Table 3: Effect of Initial Concentrations of Cr(VI) for prepared aqueous solution

Sr. No.	Conc.	Dosage mg	pH	Agitation Time Min.	Cr. removal mg/lit	% of Cr (VI) removal
1	0.04	100	6.3	180	1.116	72%
2	0.06	100	6.3	180	2.700	55%

3	0.08	100	6.3	180	3.2650	45.58%
4	0.10	100	6.3	180	5.3173	33.53%

Table 4: Effect of Initial Concentration of Cr (VI) Removal for effluent of electroplating industry

Sr. No.	Conc.	Dosage gm	pH	Agitation Time Min.	Cr. removal mg/lit	% of Cr (VI) removal
1	0.2	1	6.3	180	2.512	70.89%
2	0.4	1	6.3	180	8.314	51.67%
3	0.6	1	6.3	180	17.020	34.01%
4	0.8	1	6.3	180	28.143	22.26%
5	1.0	1	6.3	180	34.850	18.96%

Table 5 : Effect of pH on Cr(VI) removal for prepared aqueous solution.

Sr. No.	Conc.	Dosage mg	pH	Agitation Time (Min.)	Cr. removal mg/lit	% of Cr (VI) removal
1	0.1	50	2	90	2.451	75.49%
2	0.1	50	3	90	4.625	53.75%
3	0.1	50	4	90	5.214	47.86%
4	0.1	50	5	90	5.741	42.59%
5	0.1	50	6	90	6.108	38.92%
6	0.1	50	7	90	6.894	31.06%
7	0.1	50	8	90	7.124	28.76%
8	0.1	50	9	90	7.587	24.13%

Table 6 : Effect of pH (VI) removal for effluent of electroplating industry

Sr. No.	Conc.	Dosage gm	pH	Agitation Time Min.	Cr. removal mg/lit	% of Cr (VI) removal
1	1.0	0.5	2	90	14.316	66.39%
2	1.0	0.5	3	90	16.521	61%
3	1.0	0.5	4	90	18.316	57.41%
4	1.0	0.5	5	90	23.301	45.82%
5	1.0	0.5	6	90	28.728	39.28%
6	1.0	0.5	7	90	26.112	33.28%
7	1.0	0.5	8	90	30.798	28.39%
8	1.0	0.5	9	90	34.612	19.52%

Table 7: Effect of Adsorbent Dosage Cr (VI) removal for prepared aqueous solution

Sr. No.	Conc.	Absorbent dosage mg	pH	Agitation Time Min.	Cr. removal mg/lit	% of Cr (VI) removal
1	1.0	20	2.0	120	5.149	48.5%
2	1.0	40	2.0	120	4.780	52.2%
3	1.0	60	2.0	120	3.210	67.9%

4	1.0	80	2.0	120	2.301	76.99%
5	1.0	100	2.0	120	1.710	82.91%

Table 8: Effect of Adsorbent Dosage Cr (VI) removal for effluent of electroplating industry.

Sr. No.	Conc.	Absorbent dosage gm	pH	Agitation Time Min.	Cr. removal mg/lit	% of Cr (VI) removal
1	1.0	0.5	2	120	22.018	48.80%
2	1.0	1.50	2	120	19.210	55.33%
3	1.0	2.00	2	120	18.316	57.41%
4	1.0	2.50	2	120	17.143	60.44%
5	1.0	3.00	2	120	13.000	69.77%
6	1.0	3.50	2	120	15.240	64.56%

Table 9: Effect of Agitation time Cr (VI) removal for prepared aqueous solution

Sr. No.	Conc.	Absorbent dosagemg	pH	Agitation Time Min.	Cr. removal mg/lit	% of Cr (VI) removal
1	0.1	50	2	10	6.120	38.8%
2	0.1	50	2	20	5.990	40.1%
3	0.1	50	2	30	5.541	44.79%
4	0.1	50	2	40	4.110	50.15%
5	0.1	50	2	50	4.114	58.86%
6	0.1	50	2	60	4.114	58.86%

Table 10: Effect of Agitation time Cr (VI) removal for effluent of electroplating industry

Sr. No.	Conc.	Absorbent dosage	pH	Agitation Time Min.	Cr. removal mg/lit	% of Cr (VI) removal
1	1.0	1	2	20	30.912	28.12%
2	1.0	1	2	20	26.342	38.75%
3	1.0	1	2	30	22.672	47.28%
4	1.0	1	2	40	19.600	54.42%
5	1.0	1	2	50	18.423	57.49%
6	1.0	1	2	60	18.320	57.40%
7	1.0	1	2	70	18.320	57.40%

Industrial waste, laden with toxic heavy metals, notably chromium, is a major contributor to water pollution. The electroplating industry is a key offender, releasing substantial amounts of chromium into water bodies, endangering aquatic life and human health. Traditional methods to remove heavy metals, like chemical precipitation and ion exchange, often result in secondary pollution and high costs. In this study, activated carbon derived from pomegranate peels emerged as a cost-effective, environmentally friendly solution for eliminating hexavalent chromium (Cr(VI)) from both aqueous solutions and industrial effluents. The highest removal efficiency occurred at pH 2, reaching 75.49% for aqueous solutions and 70.89% for electroplating industry effluents.

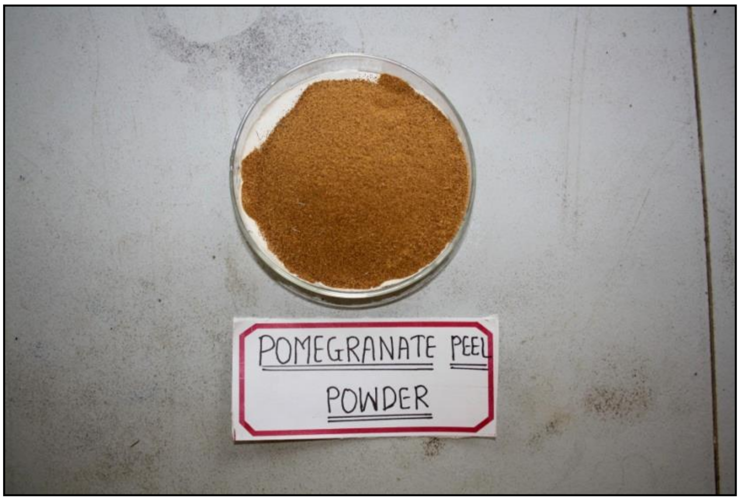

PLATE No. 1 POMEGRANATE PEEL POWDER

PLATE No. 2 ACTIVATED CARBON PREPARED BY PEELS BY USING CHEMICAL TREATMENT

4. CONCLUSION

The use of pomegranate peel-derived activated carbon offers an environmentally friendly and economical approach to mitigate the pollution caused by Cr(VI) in industrial wastewater. This study demonstrated removal efficiencies exceeding 70% for both aqueous solutions and electroplating industry effluents. With locally available materials and straightforward operational conditions, this method proves to be a practical and efficient means of addressing high concentrations of Cr(VI) in industrial wastewater. This low-cost adsorbent not only reduces operational expenses but also minimizes waste generation, making it a valuable solution for heavy metal removal.

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