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Experimental Study on the Removal of Nickel from Textile Wastewater Using Pomegranate Peel –Basedadsorbent

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ABSTRACT

Nickel contamination in textile wastewater poses a significant environmental threat because to its toxicity, persistence, and capacity to bioaccumulate in aquatic habitats. The textile industry emits significant quantities of heavy metals during dyeing and finishing procedures, with nickel identified as one of the most perilous contaminants. Exposure to nickel-contaminated water can lead to severe health issues, including organ damage and other chronic impacts, as well as disrupting aquatic ecosystems. Traditional treatment procedures, including chemical precipitation, ion exchange, and membrane filtration, are effective but frequently costly and may produce secondary waste. Consequently, there is an increasing demand for sustainable and eco-friendly solutions. This study examines the application of pomegranate peel, a by-product of juice and food processing industries, as an environmentally sustainable adsorbent for the extraction of nickel from textile effluent. The peel was harvested, desiccated, pulverized, and treated before to its application in batch adsorption studies. The influences of pH, contact duration, adsorbent quantity, and starting nickel concentration were analyzed. The findings demonstrated a notable drop in biochemical oxygen demand (BOD) of 68–75%, signifying a considerable decrease in biodegradable organic matter. The chemical oxygen demand (COD) decreased by 72–80%, indicating the elimination of oxidizable contaminants. Total dissolved solids (TDS) diminished by 55–63%, illustrating the adsorbent's efficacy in mitigating dissolved pollutants. The pH of the wastewater was modified from an initial alkaline range of 8.5–9.0 to a near-neutral range of 6.8–7.2 post-treatment. Moreover, dissolved oxygen (DO) levels increased by 40–48%, signifying improved water quality following adsorption. The results validate that the pomegranate peel-derived adsorbent successfully eliminates nickel (up to 95%) and improves the overall quality of the treated wastewater.

Key Words: Pomegranate peel, Adsorbent, Heavy metals, Textile wastewater, Nickel removal

1. INTRODUCTION

The textile industry significantly contributes to global industrial wastewater pollution. Significant volumes of chemicals and heavy metals are released into aquatic environments during dyeing and finishing procedures. Nickel is especially detrimental among these contaminants due to its toxicity, environmental persistence, and capacity for bioaccumulation. Nickel contamination presents significant hazards to human health and aquatic environments. Prolonged exposure to nickel-contaminated water may result in respiratory issues, dermatological conditions, organ impairment, and more health difficulties. In aquatic ecosystems, nickel can interfere with biological processes and impact the survival of many creatures. Conventional techniques, including chemical precipitation, ion exchange, and membrane filtration, are employed to eliminate heavy metals from wastewater. While these procedures are efficacious, they frequently incur high costs, consume significant energy, and may produce secondary pollutants. This necessitates the development of sustainable and eco-friendly treatment solutions. Adsorption has become an effective method for the removal of heavy metals owing to its

straightforwardness and efficacy. Fruit wastes are notably appealing due to their abundant availability and the presence of functional groups that can chelate metal ions. Pomegranate peel constitutes a significant by-product of fruit processing businesses and is typically regarded as waste. Its natural makeup renders it a possible bio-adsorbent for the removal of heavy metals from wastewater. The use of pomegranate peel aids in solid waste management and offers a sustainable method for the treatment of industrial effluents.

2. MATERIALS, METHODS AND PROCEDURES

2.1 Materials

2.1.1 Pomegranate Peel

Fresh pomegranate peels were procured from locally sourced fruits and meticulously rinsed using tap water to eliminate any adhering dirt, dust, and soluble contaminants. The peels were thereafter cleaned multiple times with distilled water to guarantee the thorough elimination of impurities. Subsequent to washing, the peels were uniformly arranged on sanitized trays and desiccated under direct sunlight for 2–3 days to diminish moisture content.

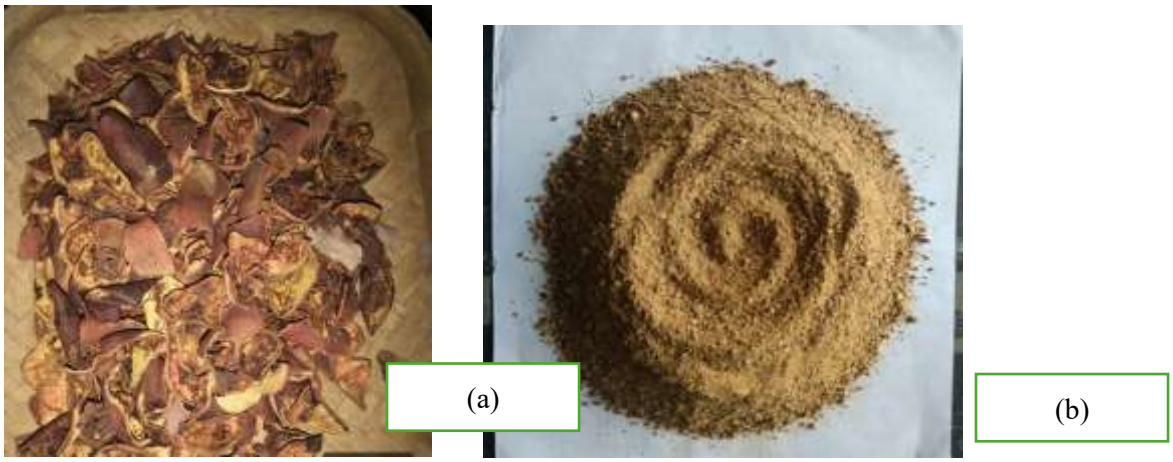

Fig.1 (a) Pomegranate Peel; (b) Pomegranate Peel powder

To guarantee the thorough elimination of remaining moisture, the sun-dried peels were additionally desiccated in a hot air oven at a temperature of 60–80°C for approximately 7 days. Effective drying is crucial to inhibit microbial proliferation and enhance adsorption efficiency. Upon complete desiccation, the peels were pulverized into a fine powder with a mechanical grinder. The ground material was subsequently sieved with a conventional sieve to achieve uniform particle size, hence enhancing surface area and improving adsorption capacity. The processed pomegranate peel powder was stored in an airtight container to safeguard it from moisture and contamination until needed. The produced adsorbent was then utilized for the extraction of nickel ions from textile effluent in batch adsorption tests.

2.1.2 Textile wastewater

The remediation of textile wastewater containing heavy metals, such as nickel (Ni^{2+}), constitutes a significant environmental issue. The textile industry releases wastewater during dyeing, bleaching, printing, and finishing processes. This effluent comprises colors, dissolved salts, suspended particles, organic materials, and heavy metals. Nickel is a hazardous, non-biodegradable, and persistent contaminant. When discharged into aquatic environments without adequate treatment, nickel can bioaccumulate in aquatic creatures and infiltrate the food chain, resulting in significant environmental and health issues. The extraction of nickel from textile wastewater via pomegranate peel-derived adsorbent mostly relies on the principle of

adsorption.

Adsorption is a surface phenomenon when atoms, ions, or molecules from a liquid phase collect on the surface of a solid substance. The substance being eliminated is referred to as the adsorbate (nickel ions), whereas the solid material utilized for removal is known as the adsorbent (pomegranate peel powder). Pomegranate peel derived from Punica granatum encompasses natural biopolymers including cellulose, hemicellulose, lignin, pectin, tannins, and polyphenolic chemicals. These components contain several functional groups, including hydroxyl (–OH), carboxyl (–COOH), and carbonyl (C=O) groups. These functional groups are crucial in the chelation of heavy metal ions. The existence of these negatively charged groups enables the adsorbent surface to attract and retain positively charged nickel ions (Ni^{2+}). The adsorption of nickel onto pomegranate skin transpires via multiple conceivable mechanisms. Ion exchange is one of the principal processes. During this process, hydrogen ions (H^{+}) or other exchangeable ions on the adsorbent surface are substituted by nickel ions from the effluent

Fig.2. Waste Water Sample

3. EXPRIMENTAL PROCEDURE

3.1 Collection of Textile Wastewater Sample

A sample of textile effluent was obtained from a local textile factory in clean plastic containers. The specimen was meticulously conveyed to the laboratory and appropriately preserved. Prior to commencing the experiment, the wastewater was permitted to settle to eliminate heavy suspended particles. The initial parameters tested included pH, BOD, COD, TDS, and nickel content.

3.2 Preparation of Pomegranate Peel Adsorbent

Fresh pomegranate peels were gathered and meticulously rinsed with distilled water to eliminate dust and contaminants. The peels were desiccated under sunshine for many days until all moisture was entirely eliminated. Upon thorough desiccation, the peels were pulverized into a fine powder utilizing a grinder. The powder was sieved to achieve a consistent particle size and stored in sealed containers for subsequent use as an adsorbent.

3.3 Batch Adsorption Experiment

A specific volume of textile wastewater was collected in sterile conical flasks. A specified amount of the produced pomegranate peel powder was incorporated into each flask. The flasks were positioned on a motorized shaker at a uniform speed to facilitate adequate mixing of the wastewater and the adsorbent. The contact duration was upheld to facilitate the adsorption of nickel onto the surface of the pomegranate peel powder. Various adsorbent doses and contact durations were evaluated to ascertain the optimal conditions for maximal nickel removal.

3.4 pH Adjustment

The pH of the wastewater sample was assessed before to commencing the experiment. The pH was altered with appropriate acidic or alkaline solutions to examine its impact on nickel removal. The adsorption experiment was performed at several pH levels to identify the optimal pH condition.

3.5 Analysis of Treated Sample

Upon concluding the adsorption procedure, the treated water sample was meticulously collected and evaluated to ascertain the residual nickel concentration and other water quality metrics. The outcomes following treatment were juxtaposed with the beginning values to assess the efficacy of the pomegranate peel-derived adsorbent in eliminating nickel from textile effluent.

3.6 Coagulation and Flocculation

Coagulation and flocculation are chemical treatment methods employed to eliminate dissolved and suspended contaminants from wastewater. In textile effluent, nickel predominantly exists as dissolved Ni^{2+} ions and occasionally adheres to tiny colloidal particles. Upon the addition of a coagulant, such as alum ($Al_2(SO_4)_3$) or ferric chloride ($FeCl_3$), to wastewater, a reaction occurs with water, resulting in the formation of metal hydroxides, specifically $Al(OH)_3$ or $Fe(OH)_3$. These hydroxides possess positive charges and assist in neutralizing the negative charges of colloidal particles and dissolved metal ions.

3.7 Adsorption

Adsorption is a surface phenomena wherein dissolved chemicals (adsorbate) collect on the surface of a solid material (adsorbent). This study examines nickel (Ni^{2+}) ions in textile wastewater as the adsorbate and pomegranate peel powder as the adsorbent.

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Fig.3.Analysis of sample

4. RESULTS AND DISCUSSIONS

The experimental findings unequivocally indicate that the pomegranate peel-based adsorbent is exceptionally efficient in eliminating nickel from textile effluent , as shown in Table.1. The preliminary examination of the gathered wastewater revealed a substantial concentration of nickel, accompanied with elevated turbidity and a mildly acidic pH, suggesting contamination from textile manufacturing operations, including dyeing and metal-based treatments. A significant decrease in nickel content was noted following treatment with pomegranate peel powder across various experimental settings.

Table.1 Water Quality Parameters

Parameter	Raw Waste Water	After Treatment			
		S1	S2	S3	S4
pH	9.0	6.8	7.5	8.2	6.2
BOD	120	16.5	22.7	20	26.8
COD	420	180	220.5	165.8	235
TDS	2800	1500	1978.2	1745.3	1879.6
DO	1.2	2.8	3.1	3.6	2.5
Alkalinity	325	180	165.2	170.3	160.6

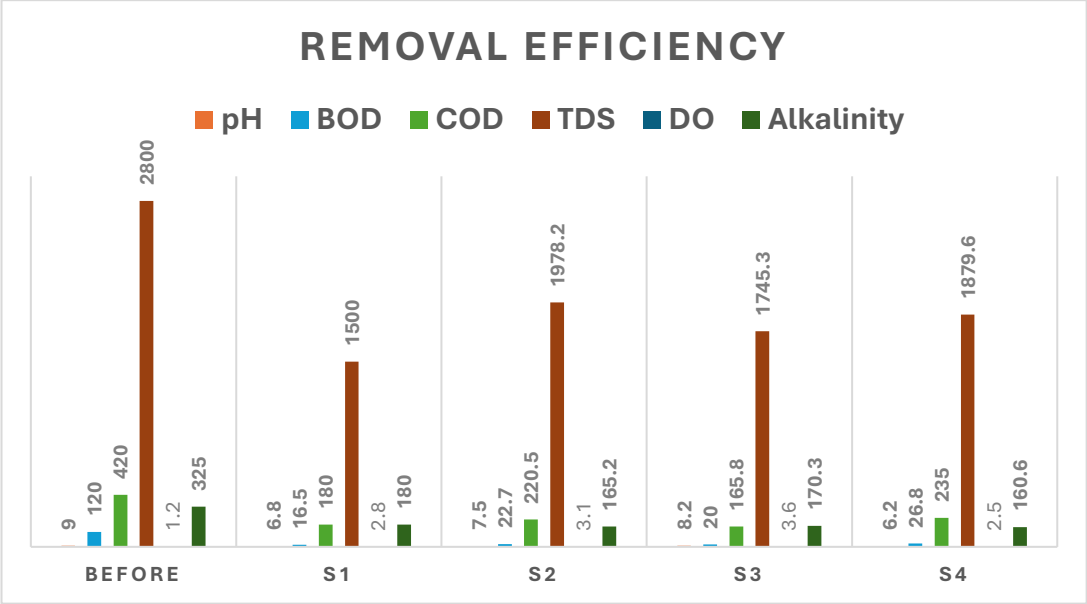

Fig.4. Removal efficiency

5. CONCLUSIONS

1) This experimental study confirms that adsorbent generated from pomegranate peel is an exceptionally effective and sustainable solution for the removal of nickel from textile effluent.

2) The results indicated that adsorption efficacy is significantly affected by operational parameters, such as adsorbent dosage, solution pH, and contact time.

3) Under optimal conditions—specifically within a pH range of 5–6, elevated adsorbent dosage, and a contact duration of around 90–120 minutes—nickel removal effectiveness surpassed 90%.

4) The study concludes that pomegranate peel, an agricultural by-product, can be converted into a cost-effective, eco-friendly, and efficient biosorbent for the removal of heavy metals.

5) Employing bio-based materials not only alleviates environmental pollution from textile effluents but also promotes sustainable waste management and resource recovery.

6) Thus, pomegranate peel–based adsorption offers a feasible and promising substitute for conventional, expensive wastewater treatment methods.

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