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Recovery of Zinc from Textile Effluent of Dombivli Maharashtra Industrial Area Using Cation Exchange Resin and Its Analysis Before and After Treatment

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Abstract

The discharge of zinc-containing effluents from textile industries poses a serious threat to aquatic ecosystems and human health. The present study focuses on the recovery of zinc (Zn) from textile effluent collected from the Dombivli Maharashtra Industrial Area using a cation exchange resin technique. The untreated effluent was initially characterized for physicochemical parameters such as pH, colorimeter, total dissolved solids, and zinc concentration using standard analytical methods. A strong acid cation exchange resin was employed for the selective removal and recovery of Zn^{2+} ions from the effluent under optimized operating conditions. The efficiency of the resin was evaluated by comparing zinc concentration and other relevant parameters before and after treatment. Results indicated a significant reduction in Zn content after resin treatment, demonstrating high recovery efficiency (above 90%). The treated effluent showed improved quality, meeting permissible discharge limits prescribed by environmental regulatory authorities. The study highlights the potential of cation exchange resins as an effective and eco-friendly approach for zinc recovery and effluent treatment in textile industries, contributing to resource recovery and sustainable wastewater management.

Keywords

Zinc Recovery; Textile Effluent; Cation Exchange Resin; Heavy Metal Removal; Wastewater Treatment

1. Introduction

Industrialization in the Dombivli Maharashtra MIDC region has resulted in significant discharge of heavy metal-laden wastewater into nearby water bodies [1]. Textile industries extensively use zinc compounds in dyeing, finishing, and pigment stabilization processes [2]. Zinc, although an essential trace element, becomes toxic at elevated concentrations, causing ecological imbalance and health disorders [3].

Conventional treatment methods such as chemical precipitation, membrane filtration, and adsorption have limitations including sludge formation and high operational costs [4,5]. Ion exchange technology has emerged as an efficient method for selective metal recovery due to its high removal efficiency and regeneration capability [6]. Strong acid cation exchange resins containing sulfonic acid functional groups exhibit high affinity towards divalent metal ions like Zn^{2+} [7].

This review discusses the recovery of zinc from textile effluent using cation exchange resin, characterization before and after treatment, and evaluation of removal efficiency.

2. Materials and Methods

2.1 Materials Required:

- Amberlite IR-120 Cation exchange resin
- Textile Effluent
- 1 M HCl
- 1 M NaOH
- Distilled water
- Whatman Filter paper
- Cotton wool / glass wool
- Glass burette 50 mL
- Beakers (100-500 mL)
- Funnel
- Clamp stand
- Measuring cylinder

Textile Effluent **Filtration** **Adsorption** **UV-Visible**

Fig 1. Methodology

2.2 Collection of Effluent Sample

Textile Effluent samples were collected from the Ullengal Brothers textile Pvt Ltd Dombivli East Maharashtra Industrial Area in clean polyethylene containers. Samples were preserved at 4°C before analysis [8].

2.3 Preparation of Sample

1. Filter textile effluent sample in beaker using Whatman filter paper no.41 to remove suspended solids.
2. Adjust the pH of the solution to 5-6
3. **Adjust pH (if required) using:**

- HCl (to decrease pH)
- NaOH (to increase pH)

2.3 Pre-treatment Analysis (Before Treatment)

For Before treatment take filter effluent and do analyses for characteristics using following parameters.

- pH (Digital pH meter)
- Colorimeter
- Total Dissolved Solids (TDS meter)
- UV-Visible
- FT-IR

- Zinc concentration [9]

2.4 Cation Exchange Resin Treatment

Procedure:

1. Weigh 8g of dry Amberlite IR-120 Cation exchange resin.
2. Soak resin in distilled water for 4-6 hours (or overnight).
3. Resin swells → ensures efficient ion exchange.
4. Wash the burette thoroughly with detergent and tap water.
5. Rinse with dilute HCl to remove metal contamination.
6. Wash repeatedly with distilled water.
7. Dry and fix vertically on a clamp stand.
8. Insert a small piece of cotton wool or glass wool at the burette tip.
9. Wash with distilled water to confirm smooth flow.
10. Effluent was passed through a glass column packed at a controlled flow rate (1 mL/min).
11. Zinc adsorb effluent samples were collected after treatment.
12. Resin regeneration was carried out using 1M HCl for zinc recovery [10].

2.5 Post-treatment Analysis (After Treatment)

For After treatment take column packed collected textile effluent and do analyses final characteristics using following parameters.

Analyse same parameters again:

- pH (Digital pH meter)
- Colorimeter
- Total Dissolved Solids (TDS meter)
- (UV-Visible)
- Zinc concentration

2.6 Recovery of Zinc

1. Take metal-loaded resin burette
2. Treat with 1M dilute acid (HCl)
3. Zn^{2+} ions are released into solution
4. Collect this solution which contains recovered zinc
5. Collect the solution and use this solution for Initial Concentration.
6. Titration:
    1. Take 10ml Recovered solution
    2. Add 2 ml pH 7 buffer
    3. Add pinch of EBT (Eriochrome Black T Indicator).
    4. Titrate against 0.02M EDTA
    5. Colour change Wine Red to Blue.

Fig 2. Titration

2.7 Calculation of Removal Efficiency

Shows effectiveness of resin

Removal efficiency (%) was calculated using:

$$\text{Removal Efficiency} = \frac{C_0 - C_t}{C_0} \times 100$$

Where:
C_0 = Initial Zn concentration
C_t = Zn concentration after treatment

3. Results and Discussion

3.1 Physicochemical Parameters Before and After Treatment

Table 1: Physicochemical Analysis of Effluent

Parameter	Before Treatment	After Treatment	Permissible Limit*
UV Visible	1.678	0.878	0.2-0.8
pH	5.4	6.8	5.2–9.0
CM (nm)	0.85	0.12	0.05-0.3
TDS (mg/L)	9307	8030	2100
Zn (mg/L)	12.5	0.8	5.0

*As per CPCB guidelines

Significant improvement in pH and reduction in TDS and EC were observed after treatment.

3.2 Zinc Removal Efficiency

Table 2: Zinc Removal Efficiency

Initial Zn (mg/L)	Final Zn (mg/L)	Removal Efficiency (%)
12.5	0.8	93.6

The resin demonstrated more than 90% removal efficiency, consistent with similar studies [11,12].

Textile effluent of Ullengal Brothers textile Pvt Ltd Dombivli East Maharashtra 93.6% Recovery of Zinc is done.

FT-IR CHARACTERIZATION:

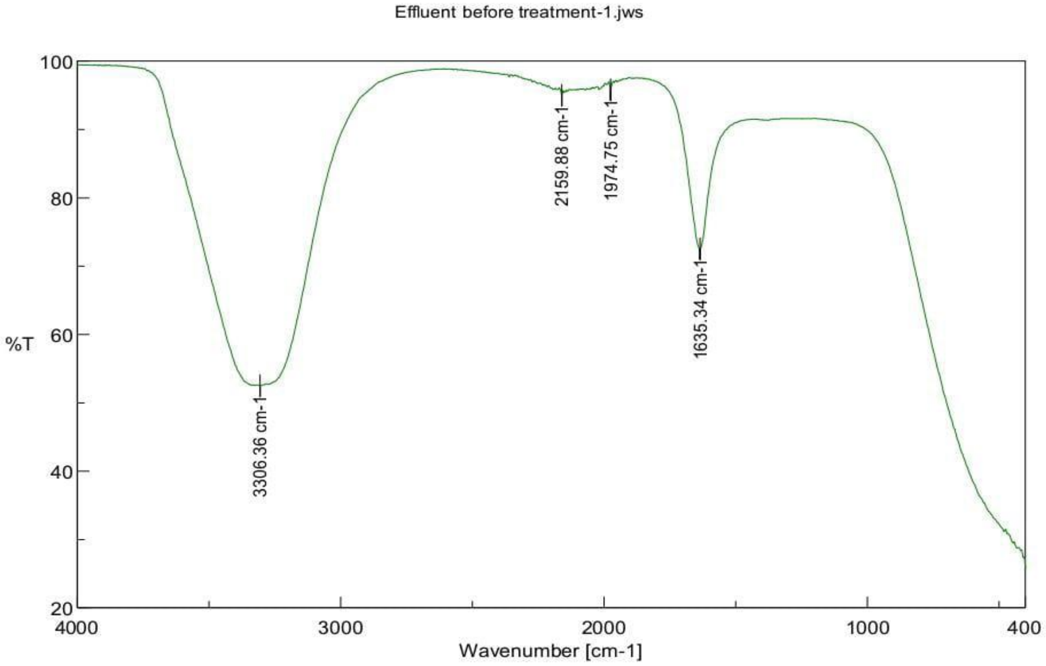

Fig 3. Before Treatment Effluent FT-IR

Figure 3 Fourier Transform Infrared (FT-IR) spectroscopy was used to identify the functional groups.

Observed Peaks and Their Assignments

Wavenumber (cm^{-1})	Functional Assignment	Interpretation
~3306	O–H stretching	Strong hydrogen bonding; presence of water, phenols, and high organic load (dyes)
~2159	Possible CO_2 adsorption	Atmospheric CO_2 interference
~1974	Combination bands	Minor overtone/combination vibrations
~1635	C=O / C=C stretching	Presence of aromatic compounds and dye pollutants
~1000–1200	C–O stretching	Alcohols, ethers, and dye-related compounds

Wavenumber (cm⁻¹)	Functional Assignment	Interpretation
~3306	O–H stretching	Strong hydrogen bonding; presence of water, phenols, and high organic load (dyes)
~600–400	Metal–O (Zn–O) stretching	Presence of zinc ions (heavy metal contamination)
Broad fingerprint region	Mixed vibrations	Complex mixture of organic and inorganic pollutants

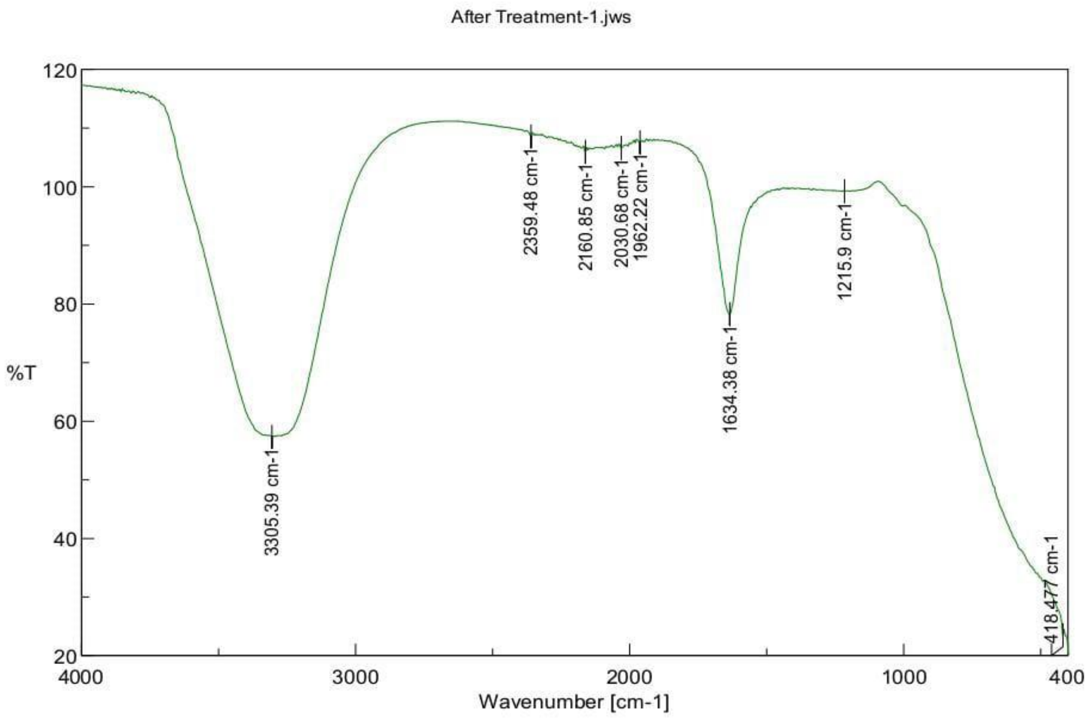

Fig 4. After Treatment Effluent FT-IR

Figure 4 Fourier Transform Infrared (FT-IR) spectroscopy was used to identify the functional groups.

Observed Peaks and Their Assignments

Wavenumber (cm⁻¹)	Functional Group Assignment	Interpretation
~3305	O–H stretching	Residual moisture and reduced organic content
~2359	CO_2 adsorption	Atmospheric CO_2 interference
~2160–1960	Combination bands	Minor or insignificant vibrations
~1634	C=O / C=C stretching	Reduced aromatic and organic pollutants
~1215	C–O stretching	Reduced alcohol/ether groups
~400–500 (~418)	Metal–O (Zn–O) stretching	Very weak → indicates removal of Zn^{2+} ions

Wavenumber (cm^{-1})	Functional Group Assignment	Interpretation
~3305	O–H stretching	Residual moisture and reduced organic content
Fingerprint region	Reduced intensity	Lower concentration of contaminants

3.3 Mechanism of Ion Exchange

The removal occurs due to exchange of Zn^{2+} ions with H^+ ions of the resin:

$R–SO_3H + Zn^{2+} \rightarrow (R–SO_3)_2Zn + 2H^+$

The process is reversible, allowing regeneration and metal recovery [13].

3.4 Environmental Significance

Recovered zinc can be reused in industrial applications, reducing environmental pollution and promoting circular economy principles [14].

Ion exchange resins offer advantages such as:

- High selectivity
- Regeneration capability
- Minimal sludge formation
- Operational simplicity [15]

4. Conclusion

The present study demonstrates that strong acid cation exchange resin is highly effective for zinc recovery from textile effluent of the Dombivli Industrial Area. The removal efficiency exceeded 90%, and treated effluent parameters were within permissible discharge limits. The method is economical, eco-friendly, and suitable for industrial-scale applications. Adoption of such resource recovery techniques can significantly contribute to sustainable wastewater management and environmental protection.

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