Bioremoval of Chromium from Textile Industrial Waste Using Bacillus Cereus

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Abstract: The release of untreated wastewater from textile industries presents a serious environmental concern, primarily due to the toxic heavy metals it contains. This study examined the removal of such metals using bacterial biomass, focusing on five effluent samples and employing the bacterial strain Bacillus cereus. Results showed that Bacillus cereus significantly reduced chromium (Cr) levels across the samples, with removal rates averaging 83.97% in Sample A, 66.90% in Sample B, 100% in Sample C, 77.78% in Sample D, and 92.16% in Sample E. Overall, the average chromium removal efficiency reached 84.16%. These outcomes highlight the viability of bacterial biomass as an environmentally friendly and economical solution for treating heavy metal pollution in textile industry effluents. The study emphasises microbial biosorption as a sustainable alternative to traditional treatment techniques, suggesting strong potential for broader application in industrial wastewater management.

Keywords: *Textile Effluents, Heavy Metals, Biosorption, Bacillus Cereus, Wastewater Treatment.*

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I. INTRODUCTION

The textile industry ranks among the world's largest manufacturing sectors, playing a key role in economic development while also producing substantial volumes of wastewater laden with dyes, chemicals, and heavy metals. Of particular environmental concern are toxic heavy metals such as cadmium (Cd), chromium (Cr), and lead (Pb), which are resistant to degradation and tend to accumulate in aquatic environments, posing long-term risks (Farooq et al., 2025). Releasing untreated textile effluents into water systems can lead to severe consequences for both ecosystems and human health, including cancer, organ damage, and disruption of aquatic life (Ali et al., 2021).

Commonly used treatment techniques such as chemical precipitation, ion exchange, and membrane filtration have proven effective in removing heavy metals but come with drawbacks. These include high operational costs, significant energy demands, and the production of secondary waste, which undermine their sustainability over time (Gupta et al., 2019; Tripathi et al., 2023). This has led to increased interest in alternative, biologically based methods, especially those leveraging bacterial biomass for metal removal. (Blaga, et al. 2021)

Bacteria offer a promising solution due to their natural ability to adsorb and accumulate metals, driven by functional groups like carboxyl, hydroxyl, and amino groups present on their cell surfaces (Waterlyst, 2024). Certain species, including Pseudomonas aeruginosa, Escherichia coli, and Enterobacter aerogenes, have shown notable effectiveness in lowering heavy metal levels in textile wastewater (Kumar et al., 2020; Singh & Chauhan, 2022). Bacillus cereus is capable of transforming Cr (VI) into the less toxic and more stable Cr (III), and in some cases, further reducing it to metallic Cr (0). This process is mediated by secreted chromium reductase enzymes that drive the chemical conversion (Mondal et al., 2025). These microbial approaches are not only cost-efficient and environmentally friendly but also resilient under extreme industrial conditions, making them viable for large-scale use (Sharma et al., 2021).

Emerging research suggests that combining different bacterial strains or integrating bacteria with microalgae can improve metal removal efficiency beyond what single strains achieve (Patel et al., 2022; Tripathi et al., 2023). Yet, much of this work has been confined to laboratory settings using simplified solutions, with little testing on real-world industrial effluents that contain complex mixtures of dyes and multiple metals (Rani et al., 2020). Bridging this gap is

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essential for translating lab findings into practical, scalable treatment strategies.

Accordingly, this study examines the potential of bacterial biomass to remove Chromium (Cr) from actual textile industry waste, evaluating the performance of specific bacterial strains. By analysing biosorption mechanisms and testing them under realistic conditions, the research supports the development of more sustainable and effective wastewater treatment solutions for the textile sector.

II. MATERIALS AND METHODS

➢ *Sample Collection*

Wastewater samples from textile industries were collected from effluent treatment plants (ETPs) in Yavatmal and Amravati. The samples were gathered in sterile plastic containers using aseptic techniques and transported to the laboratory, where they were stored at 4°C until further analysis.

➢ *Heavy Metal Analysis*

The concentration of heavy metals in the collected effluents was determined following the guidelines of the American Public Health Association (APHA).

➢ *Bacterial Isolation and Screening*

Metal-tolerant bacteria were screened using the broth dilution method. Isolated bacterial strains were identified based on standard microbiological procedures, examining their morphological, biochemical reactions, and cultural characteristics.

➢ *Molecular Identification via 16S rRNA Sequencing*

Genomic DNA was isolated from the bacterial culture, and a segment of the rDNA gene was amplified using the universal forward primer (27F): 5'-AGAGTTTGATCCTGGCTCAG-3' and reverse primer (1492R): 5'-GGTTACCTTGTTACGACTT-3', following protocols from Lane (1991) and Weisburg et al. (1991). The resulting PCR product was then prepared and subjected to Sanger sequencing.

➢ *Biomass Production*

Selected metal-tolerant bacterial isolates were grown in liquid culture using a shaking incubator to produce biomass. Different carbon sources such as glucose, sucrose, and maltose were tested to assess their effect on biomass yield. The sugar type and concentration that resulted in the highest biomass output were chosen for subsequent experiments.

➢ *Biosorption Study*

For biosorption trials, 150 mL of effluent sample was placed in Erlenmeyer flasks along with 15.0 ± 1.0 mg of bacterial biomass. The mixtures were continuously agitated at 30–35°C ± 2°C for 48 hours. After incubation, bacterial cells were separated from the solution, and the remaining metal concentrations in the treated samples were measured using atomic absorption spectrophotometry.

➢ *Removal Efficiency:*

The Removal Efficiency ($RE\%$) for each sample is calculated using the following equation:

$$RE\% = \left(\frac{C_{\text{before}} - C_{\text{after}}}{C_{\text{before}}}\right) \times 100$$

III. RESULTS AND DISCUSSION

➢ *Identification of Bacterial Isolates:*

Studies have identified certain bacterial species capable of extracting metals from water-based environments. In this study, bacterial isolates were obtained from wastewater using the serial dilution and pour plate technique on Luria-Bertani Agar enriched with chromium salts. The isolate identified was Bacillus cereus. Its biochemical properties are summarised in Table 1.

Table 1 Biochemical Characterisation of Isolated Bacteria

Characters	**Bacillus cereus**
Gram reaction	Positive (+ve)
Indole	Negative (-ve)
Methyl red	Negative (-ve)
Voges-proskeurs	Positive (+ve)
Citrate	Positive (+ve)
Catalase	Positive (+ve)
Oxidase	Positive (+ve)
Urease	Variable
Colour on Endo Agar	Colourless to Pink colour
Colour on CLED	Blue colour
Cetrimide agar	No growth

➢ *16S rRNA Sequencing of the Isolate:*

The obtained sequence was analysed Via NCBI BLAST, which indicated that the isolate belongs to Bacillus cereus. The following sequence was retrieved:

CGTGCCAGCAGMCGCGGTAATACGTARGWRRCAAG
CGTTATCCGGGAATTATTGGGCGTRAAGCGCGCRCA
MGKWGWWTCTTAWGTCTGATGTGAAAGCCCRCGG
CTCAACCGTAGARGGRTYATTKGGAWCTGGGAGAC
TTGAGTGCAGAAGAGGAAAGTGGAATTCCATGTGT
AGCGGTGAATGCGTAGAGATATRGAGGAACACCAG

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TGGCGAAGSGACTTTCTGGTCTGTAACTGACACTGA
GGCGCGAAGYGGGGGGACAACAGGATTAGATACCC
TGGYAGTCCACGCCGTAACGAT

➢ *Determination of Chromium Concentration in Textile Wastewater*

The levels of heavy metals in wastewater samples were measured using Atomic Absorption Spectrophotometry. Among the metals analysed, chromium (Cr) was detected in all samples. The concentration of chromium varied between 0.46 and 1.42 mg/l. Five samples labelled A, B, C, D, and E were chosen for analysis due to their elevated heavy metal content, as shown in Table 2.

Table 2 Determination of Chromium Concentration in Textile Wastewater

S. No	**Sample**	**Cr mg/l**
1	A	1.31
2	B	1.42
3	C	0.46
4	D	1.35
5	E	1.02

➢ *Treatment of Metals Using Bacterial Biomass (Bacillus cereus)*

Table 3 shows the decrease in heavy metal levels in the effluent sample following treatment with Bacillus cereus. Specifically, the bacterium was effective in removing chromium (Cr). The average removal efficiency for Cr reached 84.16%.

Table 3 Treatment of Metal by Bacterial Biomass (*Bacillus cereus*)

Sample	Cr (before treatment mg/l)	Cr (after treatment mg/l)	Cr Removal (%)
A	1.31	0.21	83.97
B	1.42	0.47	66.90
C	0.46	BDL	100
D	1.35	0.30	77.78
E	1.02	0.08	92.16

Sample C, Designated as Below Detection Limit (BDL), has a value of 0.00 mg/l

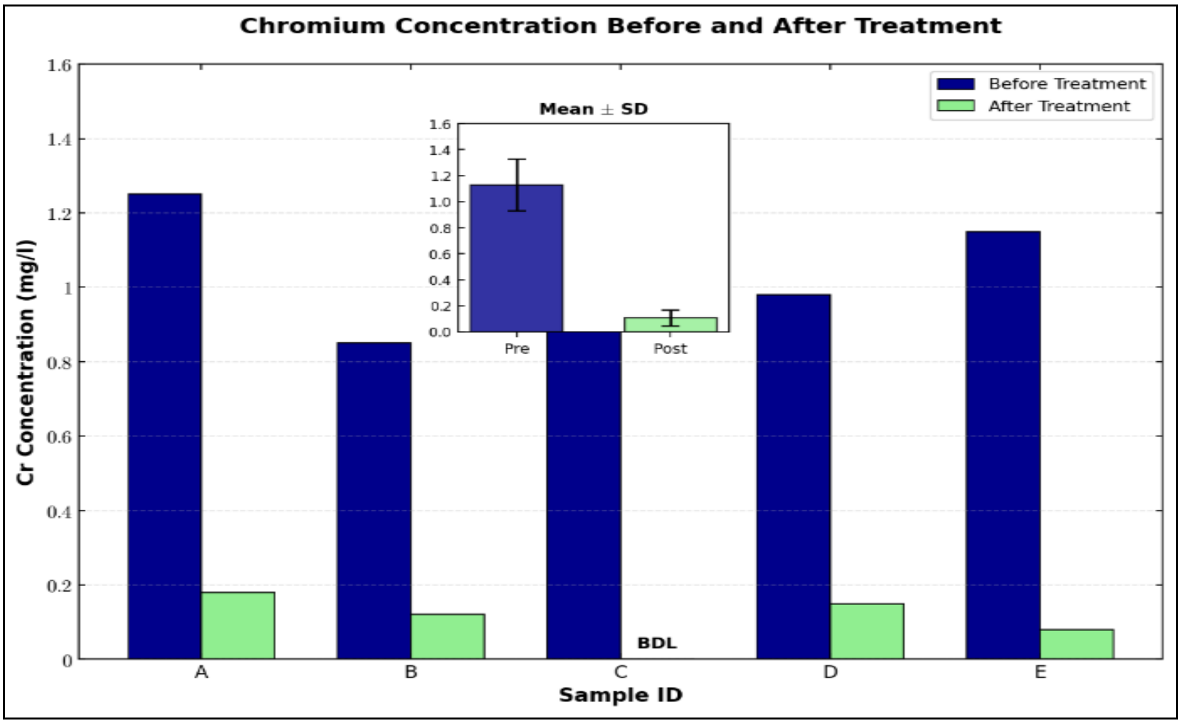

Fig 1 Chromium Concentration Before and after Treatment

IV. CONCLUSION

The findings of this study indicate that Bacillus cereus has significant potential in the bioremediation of heavy metals from wastewater generated by the textile industry. Five effluent samples were analysed to assess the bacterium's ability to remove heavy metals. Following treatment, the removal efficiency of chromium (Cr) by Bacillus cereus varied across samples: 83.97% in Sample A, 66.90% in Sample B, 100% in Sample C, 77.78% in Sample D, and 92.16% in Sample E. Overall, the average chromium removal rate achieved by Bacillus cereus was 84.16%, demonstrating its effectiveness in reducing heavy metal contamination.

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