

Heavy Metal Removal of Textile Waste Water Using Phytoremediation by Water Mosses

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DOI: <https://doi.org/10.51583/IJLTEMAS.2025.1408000028>

Abstract: The textile industry generates effluents with high concentrations of hazardous heavy metals, posing serious environmental threats if discharged untreated. In this study, an attempt was made by phytoremediation potential of *Salvinia molesta*, a free – floating aquatic macrophyte, for removing heavy metals from textile wastewater. Experiments were conducted with effluent concentrations of (25%, 50%, 75%, and 100%) and the remediation performance was assessed over 28 days (for every 7 days). The heavy metals such as Chromium (Cr), Copper (Cu), and Zinc (Zn), which are found in sample were analyzed using Atomic Absorption Spectrophotometer (AAS). Tanks containing *Salvinia molesta* showed a Cr removal rate (55.7%), Cu removal rate (48.25%), and Zn removal rate (30.50%). A one way ANOVA table was used for statistical analysis to compare the average concentrations ($p < 0.05$) for heavy metals in the effluent and removal efficiencies. This study shows an effective biological approach to treating textile industry effluent with *Salvinia molesta*, providing a sustainable solution to minimize the risks to its improper disposal.

Keywords: Phytoremediation, Heavy Metal, Atomic Absorption Spectrometry (AAS), ANOVA Table, *Salvinia molesta*

I. Introduction

Pollution refers to the introduction of harmful substances or contaminants into the environment, causing adverse effects on ecosystems, human health, and the planet's overall balance. These pollutants may be in the form of chemicals, particles, or biological materials that degrade air, water, and soil quality. Human activities such as industrial processes, urbanization, deforestation, and excessive use of non – renewable resources significantly contribute to the proliferation of pollution.[1] Additionally, natural occurrences like volcanic eruptions and wildfires can also release pollutants into the environment. The persistent rise in pollution levels has led to widespread environmental issues, including global warming, acid rain, and biodiversity loss.

The impact of pollution extends far beyond environmental damage, directly affecting human and animal health. [2-4] Contaminated water sources, for instance, lead to role in water borne diseases, while air pollution causes respiratory and cardiovascular problems. Soil degradation from industrial waste reduces agricultural productivity, threatening food security. Moreover, marine ecosystems suffer immensely from plastic and chemical waste, endangering aquatic life. Addressing pollution requires a combination of sustainable practices, stricter regulations, and community awareness. Promoting renewable energy, proper waste management, and green technologies can play waterborne diseases, while air pollution causes respiratory and cardiovascular problems. Soil degradation from industrial waste reduces agricultural productivity, a vital mitigating its effects and preserving environmental integrity for future generations.[5]

Air Pollution, Water Pollution, Soil Pollution, Radioactive Pollution, Thermal Pollution, Noise Pollution, Chemical Pollution.

Water Pollution

Water pollution has emerged as one of the most pressing global challenges, directly contributing to widespread illness and fatalities. Contaminants such as pesticides, agricultural runoff, volcanic organic compounds, waste from food production and industrial byproducts all significantly degrade water quality. Among these, heavy metals represent the most serious threat to human health due to their toxicity and persistence in the environment.

Although over three- quarters of the Earth's surface is covered by water, only a very small percentage is suitable for human use. This disparity, combined with increasing global water consumption and demand for potable water, highlights the critical need to protect and manage this vital resource. [6-8] Water is a fundamental, non-living component of the environment that sustains all forms of life. However, urbanization and industrial activities in recent decades have severely compromised the safety of many water sources.

The deterioration of water quality is a global concern exacerbated by factors such as rapid urban growth, population increases, industrial expansion, and the unsustainable use of freshwater resources. Overpopulation and inefficient waste management systems have further aggravated surface water contamination in rivers, lakes, and other freshwater bodies. The rising demand for water, driven by urbanization, industrialization, and population growth, has led to severe pollution of aquatic ecosystems, necessitating urgent action.

Giving the severity of the problem, the development and implementation of efficient biological solutions to mitigate contamination in eutrophic waters and safeguard aquatic ecosystems are of utmost importance. Addressing these issues requires a multi-faceted approach to ensure the preservation of water quality for current and future generations.

Heavy Metals

The pollution caused by heavy metals has become a significant global issue, primarily due to the release of untreated sewage and industrial waste into ecosystems and agricultural lands. Recent years have witnessed growing interest in understanding pollutant absorption and the use of biological indicators to monitor heavy metal contamination in aquatic ecosystems. Regulatory guidelines for environmental pollutants are often grounded in toxicity data derived from aquatic plants.

Heavy metals are non-biodegradable and persistent in the environment, unlike organic pollutants, hence it is necessary to reduce their concentrations before releasing them into the environment to ensure public safety. Due to their inherent value as precious resources, researchers and industrial experts are exploring innovative ways to recover these metals. Harmful heavy metals, including cadmium (Cd), zinc (Zn), chromium (Cr), lead (Pb), and copper (Cu), are well-known for their severe environmental and health impacts. Their accumulation and biomagnification through food chains present significant threats, ranging from ecosystem damage to global warming. Improper disposal of these metals without effective treatment poses grave risks to public health, leading to conditions such as cancer, organ damage, neurological disorders, and stunted growth and development. These risks underscore the urgency of adopting effective measures to mitigate metal pollution.

Various techniques have been developed to address heavy metal contamination in leachate, including chemical precipitation, oxidation or reduction, electrochemical methods, ultrafiltration, reverse osmosis, electrodialysis, membrane technologies, solvent extraction, evaporation recovery, and ion exchange processes. [9] While effective in removing pollutants, these methods often come with high costs and the potential to generate significant waste, limiting their economic feasibility.

In light of these challenges, researchers are refining strategies to develop more sustainable and cost-effective solutions. Current methods fall into categories such as recycling, filtration, biological processes, and chemical treatments. Among these, phytoremediation—using plants to absorb and purify contaminants—has gained considerable attention as a promising alternative. [10] This approach offers an eco friendly and efficient solution to mitigate heavy metal pollution, paving the way for cleaner ecosystems and improved public health outcomes. The sources of heavy metals that are been produced.

Phytoremediation

Phytoremediation refers to the process where plants accumulate, degrade, and neutralize harmful contaminants from soil, air, and water. This technique employs specific plants capable of bioaccumulating heavy metals like lead, cadmium, chromium and arsenic, along with their various radioisotopes, to clean contaminated soil and water. It is emerging as a rapidly advancing cost – effective technology. [11] Recent research is exploring the potential of chelating agents to enhance heavy metal uptake in soil – growth plants, with promising result that could make this technology commercially viable soon. Plants act as natural solar pumps, drawing and concentrating specific elements from their surroundings. Collaboration between molecular biologists, plant biochemists, soil chemists, agromists, and environmental engineers is helping to advance phytoremediation.

Phytoremediation has been successfully applied to remediate sites contaminated with radioisotopes. To better understand how plant roots absorb heavy metals from the soil, making them natural phytoremediators. [13] Despite being a cost – efficient, environmentally friendly, and aesthetically pleasing approach, phytoremediation.

Salvinia Molesta

Salvinia Molesta is a free – floating perennial aquatic weed native to southeastern Brazil. Its rapid vegetative reproduction has earned it a reputation as a serious invasive species in many regions outside its native habitat. The first case of *Salvinia Molesta* infestation was recorded in the 1950s at Veli Lake in Trivandrum, Kerala, and it was classified as a pest by 1964. This weed can choke waterways, impacting both the ecosystem directly and indirectly. It thrives in slow – moving or still waters, such as ponds, lakes, and rivers and prefers nutrient rich environments like eutrophic or polluted waters. [12] It grows optimally in water with a pH below 7.5, and its ideal temperature range is between 25 – 36 0 C. *Salvinia Molesta* can also utilized for treating black water effluent in eco – friendly sewage systems.

Thus the aim of this study is to determine the concentration of heavy metals in *Salvinia Molesta* using Atomic Absorption Spectrophotometry (AAS). The metal selected for this analysis are chromium, copper, and zinc as these are extremely toxic even at trace levels.

Objective:

- To evaluate the efficiency of *Salvinia molesta* in reducing physio chemical parameters of textile wastewater.
- To assess the potential of *Salvinia molesta* for the phytoremediation of heavy metals.
- To study the overall improvement in water quality post treatment using phytoremediation.

Highlights

- *Salvinia molesta* was employed for phytoremediation of heavy metals from textile wastewater at varying effluent concentrations (25% - 100%)

- Experiments were conducted over 28 days with periodic sampling every 7 days to monitor remediation efficiency.
- Significant removal rates were achieved for Chromium (55.7%), Copper (48.25%), and Zinc (30.50%) using Atomic Absorption spectrometer (AAS) analysis.
- Statistical analysis using one – way ANOVA confirmed significant differences in heavy metal concentrations before and after phytoremediation .
- The study demonstrates *Salvinia molesta* as an effective and sustainable biological treatment option for textile effluent management.

II. Materials and Methodology

Collection of Raw Materials

A sample of *Salvinia molesta* plants used in this research work was obtained from Kerala district. The below (Fig 1a) shows the *Salvinia molesta* plant. The *Salvinia* plant is collected in plastic bags. The collected plant samples were washed with tap water to remove the dust and sand particles present in it [18]. Then the *Salvinia* leaves are treated with KMnO_4 of 1% and placed in the container. Then the leaves are kept in the bore well water for 2 days.



Fig 1 Collection of *Salvinia molesta*

Collection of Water Sample

The below (Fig 1 b) shows the water sample was taken from the Common Effluent Treatment Plant from Thirupur industry. The waste water collected as effluent discharge water from textile industry. The analysis of the water samples reveals contamination by hazardous heavy metals, rendering them unfit for human consumption . [19]



Fig 2 a) Raw effluent of Textile waste water b) Location of Thirupur

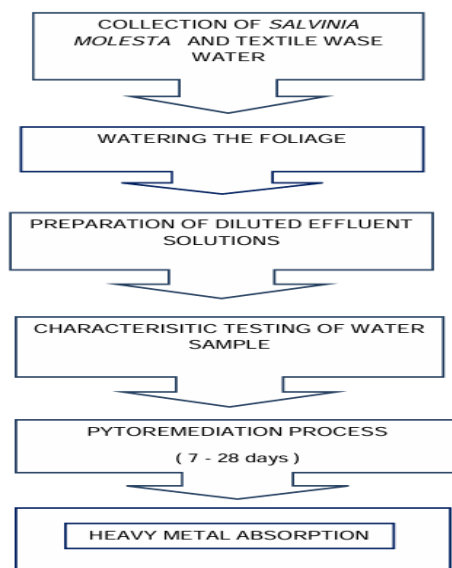
Atomic Absorption Spectrophotometer (AAS)

Atomic Absorption Spectroscopy (AAS) is used as an analytical instrument designed to measure the concentrations of specific elements in a sample, typically in trace amounts. This method relies on the absorption of light by free atoms in the gaseous state. Each element absorbs light at a characteristic wavelength, allowing for precise identification and quantification. The AAS instrument consists of several key components, including a light source (usually a hollow cathode lamp), an atomizer, a monochromator, a detector, and a data processing system. The hollow cathode lamp emits light specific to the element being analyzed. The sample is introduced into the atomizer, which converts the sample into free atoms by processes like flame atomization or graphite furnace heating. The monochromator isolates the desired wavelength corresponding to the element under investigation, while the detector measures the intensity of light absorbed by the sample. The amount of light absorbed is directly proportional to the concentration of the element in the sample, based on Beer-Lambert's law. AAS is a versatile technique used in various fields, such as environmental analysis, food quality testing, pharmaceutical research, and industrial applications. It is particularly effective for detecting metals and metalloids, such as lead, mercury, cadmium, and arsenic, in different types of samples, including water, soil, and biological materials. [14]



Fig 3 AAS instrument

Methodology



Physio Chemical Parameters

Textile wastewater requires analysis through a variety of physio chemical parameters to assess its quality and environmental impact [15]. Physical tests should be conducted to evaluate its visible and measurable characteristics, including pH, total solids (TS), total dissolved solids (TDS), and temperature. On the other hand, chemical tests are essential for determining factors such as Chemical Oxygen Demand (COD), Biological Oxygen Demand (BOD), Hardness, and Chlorides etc.

S.NO	EFFLUENT SAMPLE	EFFLUENT RANGE
pH	9.78	6 – 9
COD	1275mg/L	350 – 700mg/L
BOD	600mg/L	150 - 350mg/L
TSS	1348mg/L	200 - 1100mg/L
TDS	2120mg/L	1500 - 2200mg/L
ELECTRICAL CONDUCTIVITY	1060 μ S/cm	600 μ S/cm
CHLORIDES	550mg/L	200 - 500mg/L
HARDNESS	410mg/L	500mg/L
TEMPERATURE	35°C	30 – 40°C

Table 1: Pre – treatment process

Elements Absorbed from Textile Waste Water by Atomic Absorption Spectrometry (AAS)

Heavy metals contamination in wastewater is a critical environmental concern due to their toxicity, persistence, and bioaccumulation potential. The primary focus of this analysis is on Chromium, Copper, and Zinc, which are often discharged in textile effluents. These metals were analyzed using Atomic Absorption Spectrometry at specific wavelengths to determine their concentrations. [16]

Table 2 : Through AAS heavy metals absorbed the wavelenghts

HEAVY METALS	Initial Concentration	WAVE LENGTHS
CHROMIUM	1.6 mg/L	357.9 nm
COPPER	3.0 mg/L	328.7 nm
ZINC	4.5 mg/L	214.9 nm

Characterization of AAS Testing Period for Chromium

For 7 days the concentration and absorbance

Table 3: Concentration and absorbance for 7 days

Concentration of Cr(%)	Absorbance	Wavelength
25%	0.18	357.72
50%	0.25	357.65
75%	0.32	357.58
100%	0.40	357.50

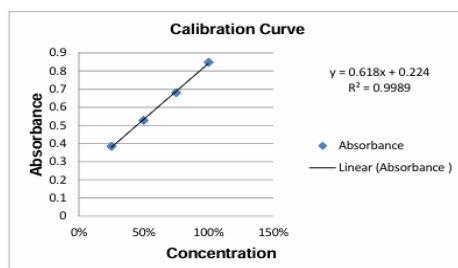
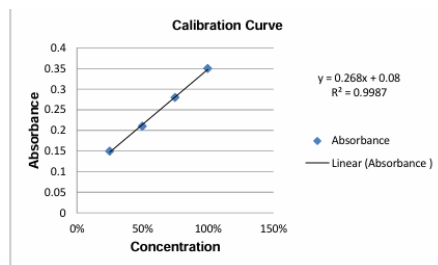


Table 3a): Concentration and absorbance for 14 days

For 14 days concentration and absorbance

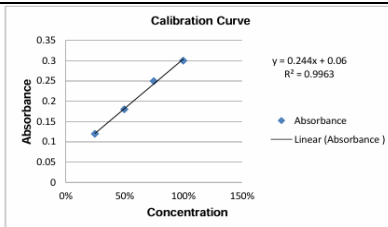
Concentration of Cr(%)	Absorbance	Wavelength
25%	0.15	357.57
50%	0.21	357.44
75%	0.28	357.3
100%	0.35	357.15



For 21 days the concentration and absorbance

Table 3b): Concentration and absorbance for 14 days

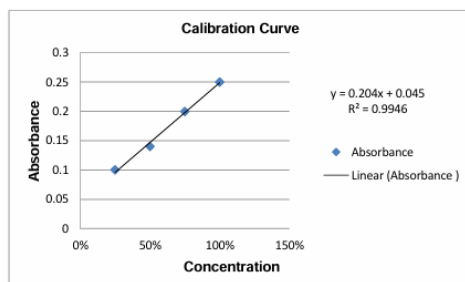
Concentration of Cr(%)	Absorbance	Wavelength
25%	0.12	357.45
50%	0.18	357.26
75%	0.25	357.05
100%	0.30	356.85



For 28 days the concentration and absorbance

Table 3c): Concentration and absorbance for 14 days

Concentration of Cr(%)	Absorbance	Wavelength
25%	0.10	357.35
50%	0.14	357.12
75%	0.20	356.85
100%	0.25	356.6

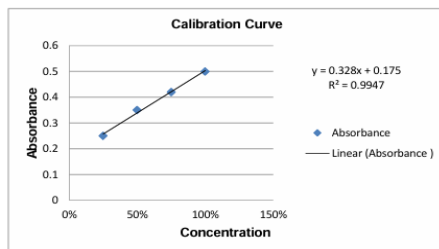


(ii) For Copper

For 7 days the concentration and absorbance

Table 3d): Concentration and absorbance for 14 days

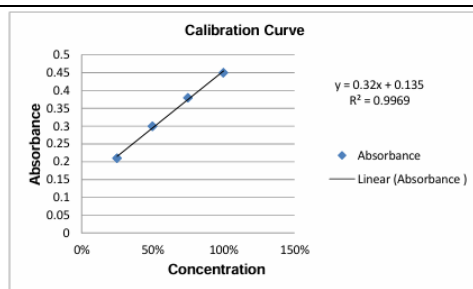
Concentration of Cu(%)	Absorbance	Wavelength
25%	0.25	328.45
50%	0.35	328.35
75%	0.42	328.28
100%	0.50	328.20



For 14 days the concentration and absorbance

Table 3e): Concentration and absorbance for 14 days

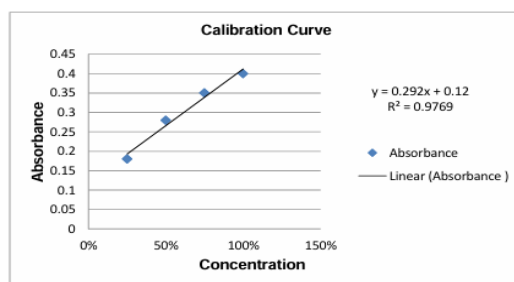
Concentration of Cu(%)	Absorbance	Wavelength
25%	0.21	328.24
50%	0.30	328.05
75%	0.38	327.9
100%	0.45	327.75



For 21 days the concentration and absorbance

Table 3f): Concentration and absorbance for 14 days

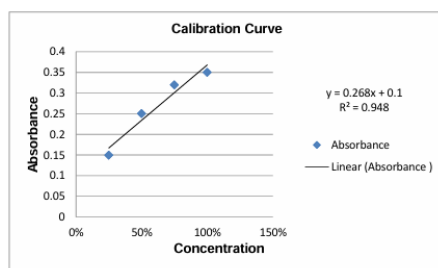
Concentration of Cu(%)	Absorbance	Wavelength
25%	0.18	328.06
50%	0.28	327.77
75%	0.35	327.55
100%	0.40	327.35



For 28 days the concentration and absorbance

Table 3g): Concentration and absorbance for 14 days

Concentration of Cu(%)	Absorbance	Wavelength
25%	0.15	327.91
50%	0.25	327.52
75%	0.32	327.23
100%	0.35	327.0

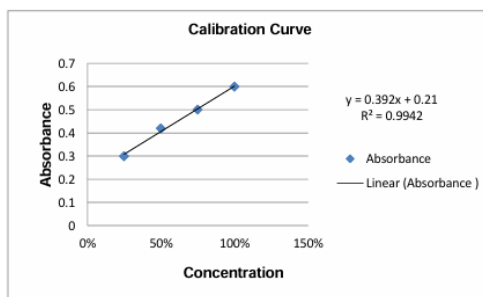


(iii) For Zinc

For 7 days the concentration and absorbance

Table 3h): Concentration and absorbance for 14 days

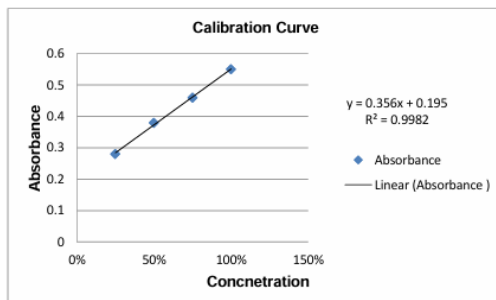
Concentration of Zn(%)	Absorbance	Wavelength
25%	0.30	214.6
50%	0.42	214.48
75%	0.50	214.4
100%	0.60	214.3



For 14 days the concentration and absorbance

Table 3i): Concentration and absorbance for 14 days

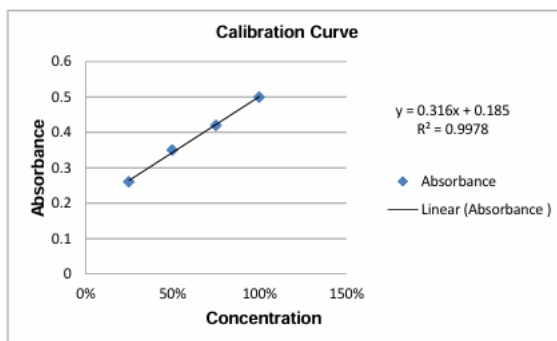
Concentration of Zn(%)	Absorbance	Wavelength
25%	0.28	214.32
50%	0.38	214.1
75%	0.46	213.94
100%	0.55	213.75



For 21 days the concentration and absorbance

Table 3j): Concentration and absorbance for 14 days

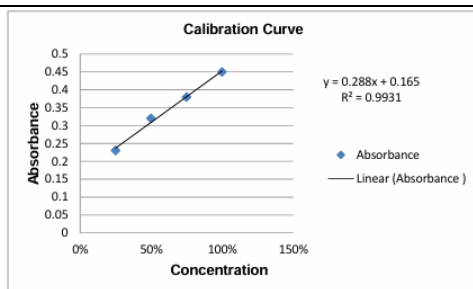
Concentration of Zn(%)	Absorbance	Wavelength
25%	0.26	214.06
50%	0.35	213.75
75%	0.42	213.52
100%	0.50	213.25



For 28 days the concentration and absorbance

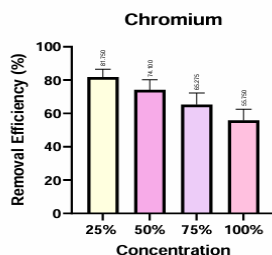
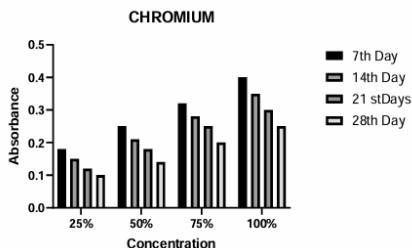
Table 3k): Concentration and absorbance for 14 days

Concentration of Zn(%)	Absorbance	Wavelength
25%	0.23	214.09
50%	0.32	213.43
75%	0.38	213.14
100%	0.45	213.30

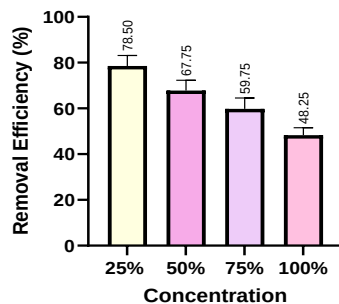
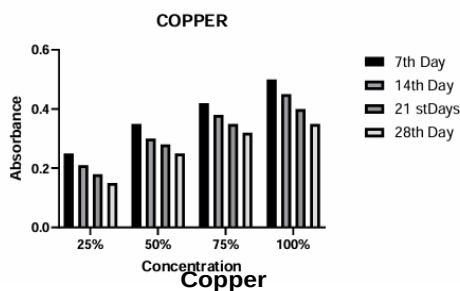


III. Result and Discussion

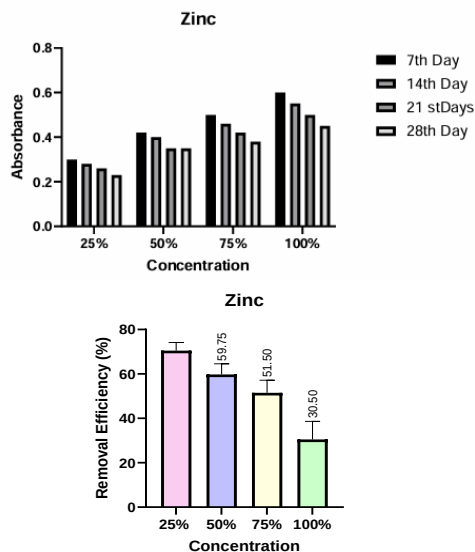
ANOVA Table



The absorbance data for chromium at concentrations of 25%, 50%, 75%, and 100% over 7, 14, 21, and 28 days indicates a clear trend of decreasing values across all concentrations. At 25% and 50% absorbance levels were initially higher on the 7th day but showed a marked and consistent decline by the 28th day, suggesting efficient chromium removal over time. In contrast, 75% and 100% concentrations maintained relatively higher absorbance values throughout the study, although a gradual decline was still observed. These results suggest that chromium is removed more rapidly at lower concentrations, while higher concentrations require extended treatment periods to achieve noticeable reductions. Overall, the findings confirm the time – dependent nature of the removal process, with greater efficiency observed at lower chromium concentrations.[\[17\]](#)



Copper absorbance values at 25%, 50%, 75%, and 100% concentrations were monitored over the same four week period. At 25% absorbance remained low and steadily decreased over time, indicating effective and rapid copper removal. The 50% concentration displayed moderate initial absorbance with a progressive decline, suggesting gradual removal efficiency. For 75% and 100% the absorbance values remained comparatively higher, with a slower rate of decline observed over the study period. This pattern reflects a time – dependent removal process, where lower concentrations facilitate faster copper elimination, while higher concentrations require longer durations for substantial reduction. The data highlights that copper removal efficiency is greater at lower initial concentrations.



The absorbance levels of zinc at varying concentrations (25%, 50%, 75% and 100%) over four time intervals 7th, 14th, 21st, and 28th days. At 25% concentration, the absorbance values remain low and show a gradual decline over time, indicating effective zinc removal at this level. At 50% concentration, the absorbance starts at a moderate level on the 7th day and decreases steadily over the following weeks, reflecting gradual removal efficiency. Higher concentrations, such as 75% and 100% exhibit relatively higher absorbance values on the 7th day, with a noticeable reduction over time. However, the removal rate at these higher concentrations is slower, as the absorbance values remain elevated compared to lower concentrations. The overall trend suggests that zinc removal efficiency improves with time, especially at lower concentrations, while higher concentrations require longer durations to achieve significant reductions. The highlights the time dependent behavior of zinc removal and the challenges associated with higher pollutant loads.[20]

IV. Conclusions

The following conclusions were drawn from the present study. The obtained heavy metals has been characterized to check for various parameters.

1. The result of this investigation suggest that *Salvinia molesta* is effective at eliminating heavy metals from textile wastewater.
2. The present study aims the efficiency of phytoremediation with *Salvinia molesta* using AAS instrument.
3. The floating aquatic plant *Salvinia molesta* was more effective at removing Cr, Cu, and Zn with removal efficiencies of (55.7%), (48.25%), and (30.50%) for 28 days.
4. The post treatment and pre treatment after 28 days has been taken the physio chemical parameters.
5. Through the graph we conclude that the removal efficiency was more in 25% concentration of Cr(81.7%), Cu(78.5%) and Zn(76.4%).

Acknowledgements The authors express their deep gratitude to the Government College of Technology, Coimbatore, Tamil Nadu. The authors are grateful to Dr.R.Bhuvaneswari (Assistant Professor) for her help and support during my project.

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