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PHYTOREMEDIATION OF TEXTILE WASTEWATER USING AQUATIC FREE-FLOATING PLANT: A SUSTAINABLE APPROACH FOR WATER TREATMENT

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Abstract

The study aims to summarize the phytoremediation potential of *Limnobium spongia* and its effectiveness in the removal of heavy metals and phosphorus from wastewater. The plants were kept in the Bagru industrial textile wastewater and Sanganer industrial textile wastewater for the observation of metal and phosphorus extraction for 28 days. The plants were collected after 28 days and determined for Heavy metal and phosphorus analysis with the help of an Atomic Absorption Spectrophotometer. The result shows that *Limnobium spongia* accumulates heavy metals and phosphorus from Bagru and Sanganer industrial wastewater but with time plant growth also deteriorates because of the physiochemical and heavy metal toxicity of wastewater. In conclusion, This information aids in understanding that *Limnobium spongia* presents a valuable approach for heavy metal analysis and assessment of environmental pollution.

Keywords:- Phytoremediation, Contamination, Industrial wastewater, Heavy metals, Atomic Absorption Spectrophotometer (AAS).

Introduction

Worldwide, industrial water contamination is a serious environmental issue. Industries release a range of pollutants, including pesticides, organic compounds, heavy metals, and other dangerous substances, into water bodies. These contaminants can endanger human health and have detrimental effects on aquatic life. They can also taint sources of drinking water. Chemical and petrochemical factories, pulp and paper mills, textile mills, and food processing plants are a few of the businesses with a reputation for polluting waterways. These companies effluents may contain hazardous substances and metals, which can contaminate the water. Many nations have guidelines and laws in place to restrict the number of pollutants that industry can release into water bodies in order to solve this issue.

The textile industry is one of the major industries which produces a large amount of pollution every day and it is also called the main creator of effluent wastewater (Mia et al., 2019). Textile dyes are known to significantly impact the physicochemical parameters of water bodies when they are discharged into aquatic ecosystems without proper treatment. There are worries regarding the environmental impact of the wastewater produced by the dyeing and printing processes (Chen et al., 2006). Textile dyes are made from synthetic compounds that contain toxic substances such as heavy metals, aromatic amines, and other hazardous chemicals. In the dyeing process, majorly azo dyes are used as they provide excellent resistance to color fading. These azo dyes can cause cancer and release aromatic amines which are released from the dyed textile when in contact with sweat or skin (Chung 2016). The discharge of textile dye wastewater into water bodies can cause a decrease in dissolved oxygen levels due to the consumption of oxygen by microorganisms during the biodegradation of dyes. The release of organic compounds from the dye wastewater can also increase the BOD and COD levels in the water, making it more difficult for aquatic organisms to survive. Textile dyes also contain heavy metals in the effluent which may increase the fertility of the sediment and water column and so cause eutrophication, which can eventually cause an oxygen shortage, an algal bloom, and the death of aquatic life (Tkaczyk et al., 2020). The presence of dyes in water can also lead to an increase in turbidity, which can block light penetration and affect photosynthesis in aquatic plants. Furthermore, textile dye wastewater can contain high levels of TDS and TSS, which can have adverse effects on aquatic life and can also make water unsuitable for human consumption.

Bioremediation with the help of plants is an environmentally friendly technology that uses plants to remove pollutants from the environment and it is also called phytoremediation. This technology is based on the ability of some plants to absorb and accumulate pollutants from the soil or water, metabolize them, and convert them into less harmful forms or store them in their tissues. There are various phytoremediation techniques including phytoextraction, phytostabilization, phytodegradation, phytovolatilization, and Rhizofiltration (Islam 2022). The use of plants in phytoremediation has several advantages over traditional remediation methods, such as being cost-effective, environmentally friendly, and sustainable. When it comes to absorbing, metabolising and transforming pollutants, plants have special physiological and biochemical mechanisms that make them efficient environmental cleanup agents. The study conducted by the researchers Napaldet and Buot (2020) in the Balili River Philippines, aimed for phytoremediation of heavy metals, particularly mercury (Hg) and lead (Pb) by *Amaranthus spinosus, Eleusine indica, and Pennisetum purpureum* species. The *P. purpureum* plant shows the highest potential for Hg uptake and translocation, and Pb uptake. In contrast, E. indica exhibited the highest Pb internal transfer, while *A. spinosus* had the highest Hg accumulation in its leaves and Pb in its stem. The *Trapa natans* plant was studied for a hyperaccumulation of heavy metals from the Kashmir wetland which is highly polluted. The studies showed that *T. natans* is capable of bioaccumulating Zn, Pb, Al, and Cr heavy metals from the site (Ahmad et al. 2023). The (Ansari et al. 2020) describe that certain aquatic macrophytes such as *Azolla, Eichhornia, Lemna, Potamogeton, Spirodela* and *Wolfialla* have been reported to be highly efficient in reducing aquatic contamination through bioaccumulation of contaminants in their body tissues. *Water hyacinth (Eichhornia)* is highly resistant and can bioremediate the toxicity of heavy metals, phenols and acids, even at high concentrations. Plants such as *Hydrocharis morsus-ranae and Ceratophyllum demersum L.* are recently studied and proven to be capable of phytoremediation of cadmium (Cd) from aquatic habitats (Gałczyńska et al. 2022, and Aasim et al. 2023). The phytoremediation potential of *Eichhornia crassipes* for the removal of Cr and Li over a period of 20 days is studied. The results showed that *E. crassipes* had a high potential for phytoremediation of Cr and Li, with maximum removal efficiencies of 99.9% and 94.6%, respectively, at the highest concentration tested (Hayyat et al. 2023). The novel Hyperaccumulator species of hexavalent chromium is fern *Pteridium aquilinum* which is used for phytoremediation of (Cr VI) contamination. The study aimed to test the accumulation and removal of Cr VI in both the gametophyte and sporophyte phases of the fern. Despite having a low translocation index towards the leaves, the study found that sporophytes demonstrated better Cr uptake than gametophytes in rhizomes and adventitious roots. (Eslava-Silva et al. 2023).

In this paper, we examine the growth as well as the capacity of removing heavy metals from the selected wastewater site by the *Limnobium spongia* also called as American frogbit plant. It is a type of aquatic plant that has leathery rounded or somewhat heart-shaped, green leaves that are attached to roots. This plant species is selected because it is a perennial plant, fast reproduction, is easy to maintain, and easy to manipulate. The experiment was performed in the winter season.

Materials and Methods

1) Instrument and reagent

Water samples from the textile industry collected from Bagru and Sanganer district Jaipur, *Limnobium spongia* plant, tap water, five tubs, Pyrex glass beakers, HCL(2N), HNO3, Atomic Absorption Spectrophotometer (AAS).

2) Experiment procedure

The samples of wastewater are collected from the Bagru and Sanganer textile industries in sampling water bottles. Further, plants are grown in clear water with controlled environmental conditions for their better growth for 2 months. Once, their proper growth is achieved all plants are divided equally and transferred into two different samples Bagru textile industrial wastewater and Sanganer textile industrial wastewater. The plants were kept in the control and experimental tubs for observations of morphological changes for 28 days of experimental duration. At the end of 28 days, all the remaining plants are collected for heavy metal and phosphate analysis which is determined with the help of an Atomic Absorption Spectrophotometer (AAS).

3) Estimation of Heavy metal accumulation in *Limnobium spongia*

The hot plate acid digestion method was employed to prepare samples of *Limnobium spongia* from Bagru and Sanganer industrial wastewater for heavy metal analysis using an Atomic Absorption Spectrophotometer (AAS). The roots and leaves of the plant were separately used for sample preparation. Firstly, 1 gram of both the root and leaf samples from Bagru wastewater were individually placed in separate dishes and dried in a furnace at 80°C. After cooling, the samples were digested using 5 mL of HCl and 10 mL of HNO_3, respectively. The root and leaf samples were heated at 100°C for 1 hour and then filtered using filter paper into separate flasks. Distilled water was added to each flask to bring the volume up to 50 mL. Similarly, *Limnobium spongia* samples harvested from Sanganer industrial wastewater underwent the same procedure for sample preparation—finally, all four samples, one root sample from Bagru and another from Sanganer industrial wastewater. Additionally, two leaf samples were taken from Bagru and Sanganer wastewater. The heavy metal content in these samples was assessed using an Atomic Absorption Spectrophotometer (AAS).

Result and Discussion

The *Limnobium spongia* exhibited the ability to accumulate significant amounts of heavy metals. The high concentrations of heavy metals and phosphorus were observed in the roots and leaves of the plant, indicating its capacity for metal uptake from the surrounding water. The bioremediation process in wastewater treatment, various morphological changes can occur in plants as they interact with and respond to the contaminants and the environment as shown below.

Table 1: Morphological changes observed in *Limnobium spongia* during an experiment.

Days	Bagru	Sanganer
1	Plants are in normal and active condition.	Plants are in normal and active condition.
7	Many of the plant leaves turned green color to yellow	Some of the leaves turned yellow color from the edges
14	Some plants died while others remained in the same condition except some leaves got rotten and fell. Roots shredding was also seen.	Some plants died. In the remaining plants maximum leaves turned yellow in color and cuts are seen at the edges of leaves.
28	Maximum plants died some are left. The remaining plants turned black in color. Each plant is left with two to four root strands.	From the remaining plants, 2 plants still have green-yellow leaves with fewer root strands while others turned black in color.

Fig:1 Morphological changes observed in L. spongia after 28 days

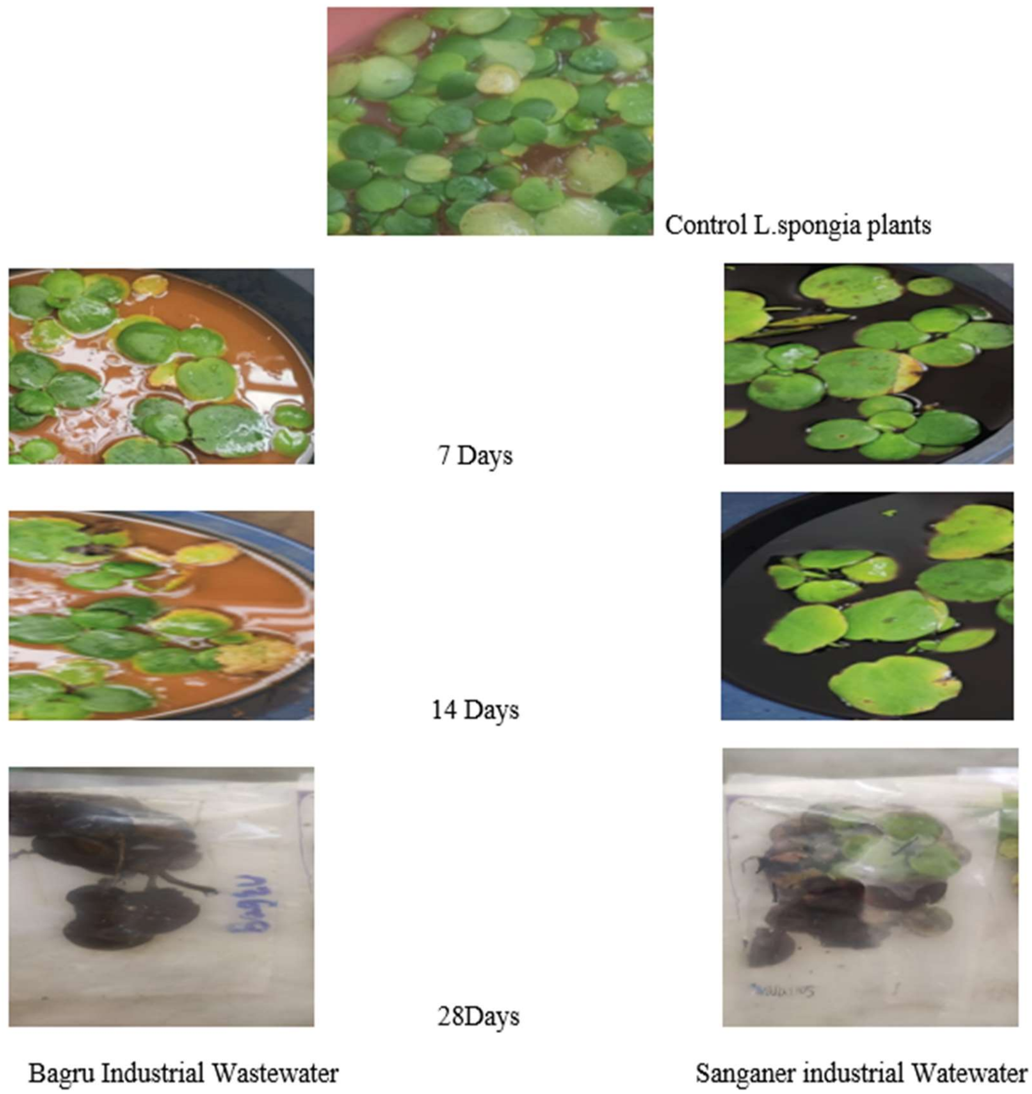

Table 2: Removal of heavy metals and Chemical Compound by leaves of aquatic weed in wastewater after 28 days.

S.no.	**Heavy metals and Chemical Compound**	**Bagru Industrial wastewater(mg L^{-1})**	**Sanganer Industrial Wastewater(mg L^{-1})**
1	Iron	0.014	0.013
2	Copper	0	0
3	Manganese	0.031	0.029
4	Zinc	0.034	0

5	Phosphate	0.92	0.012

In Bagru textile wastewater, it has been observed that the leaves of *Limnobium spongia* accumulate iron (0.014), manganese (0.031), and zinc (0.034), while the value of copper is zero. The highest accumulation is observed for phosphate (0.92) as shown in Table 2. In Sanganer textile wastewater, the leaves of the plant *L. spongia* have shown the ability to accumulate iron (0.013), manganese (0.029) and Phosphate (0.012) whereas copper and zinc are very low almost non-traceable. These results indicate that *L. spongia* can remove heavy metals by bio-accumulation of the metals. The efficiency of a plant in accumulating heavy metals is primarily dependent on its growth stage and root architecture (Rascio and Navari 2011). In our experiment, the plants used are young and actively growing along with larger root systems.

Table 3: Removal of Heavy metals and Chemical Compound from wastewater by roots of aquatic weed after 28 days.

S. No.	Heavy metals and chemical compound	Bagru Industrial wastewater(mg L^{-1})	Sanganer Industrial wastewater(mg L^{-1})
1	Iron	0.013	0.044
2	Copper	0	0
3	Manganese	0.033	0.027
4	Zinc	0.036	0
5	Phosphate	0.94	0.010

The roots of plants actively participated in the bioaccumulation of heavy metals from both Bagru and Sanganer textile wastewater. In Bagru industrial wastewater, the roots showed bioaccumulation of iron (0.013), manganese (0.033), zinc (0.036), and phosphate (0.94), while copper was not detectable. Similarly, in Sanganer industrial wastewater, the roots exhibited bioaccumulation of iron (0.044), manganese (0.027) and phosphate (0.010). It is important to note that the accumulation of heavy metals by the roots was higher in Bagru wastewater compared to Sanganer wastewater. This indicates that the root system of the plants plays a significant role in the uptake and accumulation of heavy metals, and it appears to be more efficient in the case of Bagru industrial wastewater.

Conclusion

Wastewater generated by the textile industry becomes heavily polluted due to the presence of various toxic chemicals, dyes and other harmful pollutants, leading to severe contamination. Phytoremediation is a technology that uses green plants to clean up contaminants from the atmosphere. To remediate heavy metals from contaminated areas, phytoremediation is a cheap, simple, and environmentally beneficial solution. Our research indicates that the *Limnobium spongia*, which is a free-floating, perennial, and simple to grow and manage plant has the potential to function as a bioaccumulator of heavy metals like Iron, Copper, Manganese, Zinc as well as chemical compounds like phosphorus from textile wastewater from Sanganer and Bagru. The study demonstrated that *L. spongia* leaves and roots effectively contribute to the bioremediation process, reducing the potential environmental risk of untreated wastewater. However, it is noteworthy that the accumulation of contaminants is often lower during the winter season. This phenomenon can be attributed to several factors, including the decreased metabolic activity of plants during the cold months and the reduced development of root systems, which are vital for the efficient uptake of pollutants. Furthermore, to optimize the efficiency of phytoremediation, it's essential to consider the number of plants involved and the availability of an ample water supply. The *L. spongia* represents a promising and sustainable solution for environmental remediation showcasing its significant promise in the process of phytoremediation.

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