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Study of Heavy Metal Accumulation and Phytoremediation Ability of Aquatic Plants in Gomti River, Lucknow (India)

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ABSTRACT

Aquatic plants play an important role in maintaining the ecological balance of freshwater ecosystems and are widely used in the removal of toxic metals from polluted water bodies. The present study was conducted to assess the level of heavy metal contamination and the phytoremediation potential of selected aquatic plants in the Gomti River flowing through Lucknow city (U.P.), India. Rapid urbanization, industrial discharge, domestic sewage, and agricultural runoff have significantly contributed to the deterioration of water quality in the river, leading to the accumulation of toxic metals such as Cadmium (Cd), Copper (Cu), and Arsenic (As).

In this investigation, aquatic plant species including *Hydrilla verticillata*, *Sagittaria japonica*, *Botomus umbellatus*, and *Ranunculus sceleratus* were collected from different sampling sites along the Gomti River. Samples were analyzed to determine the concentration of heavy metals accumulated in plant tissues. The results revealed that the selected aquatic plants showed different capacities for metal accumulation. *Hydrilla verticillata* exhibited higher accumulation of Arsenic, *Sagittaria japonica* showed greater uptake of Cadmium, while *Botomus umbellatus* accumulated higher concentration of Copper. In contrast, *Ranunculus sceleratus* showed comparatively lower accumulation of heavy metals.

The findings indicate that aquatic macrophytes have significant potential for the removal of toxic metals from polluted water and can be effectively used in phytoremediation techniques. The study highlights the importance of using natural and eco-friendly methods for controlling heavy metal pollution in river water. The results of this research may be useful for environmental monitoring, pollution management, and sustainable restoration of freshwater ecosystems.

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INTRODUCTION

Aquatic plants are an essential component of freshwater ecosystems and play a significant role in maintaining ecological balance as well as improving water quality. These plants contribute to primary productivity and provide habitat for aquatic organisms. In recent decades, the problem of heavy metal pollution in water bodies has increased rapidly due to industrialization, urbanization, and expansion of agricultural activities. Toxic metals released into rivers and lakes through industrial effluents, domestic sewage, agricultural runoff, and urban waste have become a major environmental concern. Heavy metals such as Cadmium (Cd), Copper (Cu), Nickel (Ni), Arsenic (As), and Chromium (Cr) are non-biodegradable and can accumulate in water, sediment, and living organisms, causing harmful effects on aquatic life and human health.[1]

Aquatic macrophytes have the ability to absorb and accumulate heavy metals from contaminated water and sediments. Because of this property, they are widely used in environmental studies to monitor pollution levels and to evaluate the possibility of phytoremediation. The accumulation of heavy metals in aquatic plants depends on the species of plant, the type of metal, and environmental conditions. Certain aquatic plants such as *Hydrilla verticillata*, *Sagittaria*

[1] APHA, *Standard Methods for the Examination of Water and Wastewater*, American Public Health Association, Washington D.C., 2012.

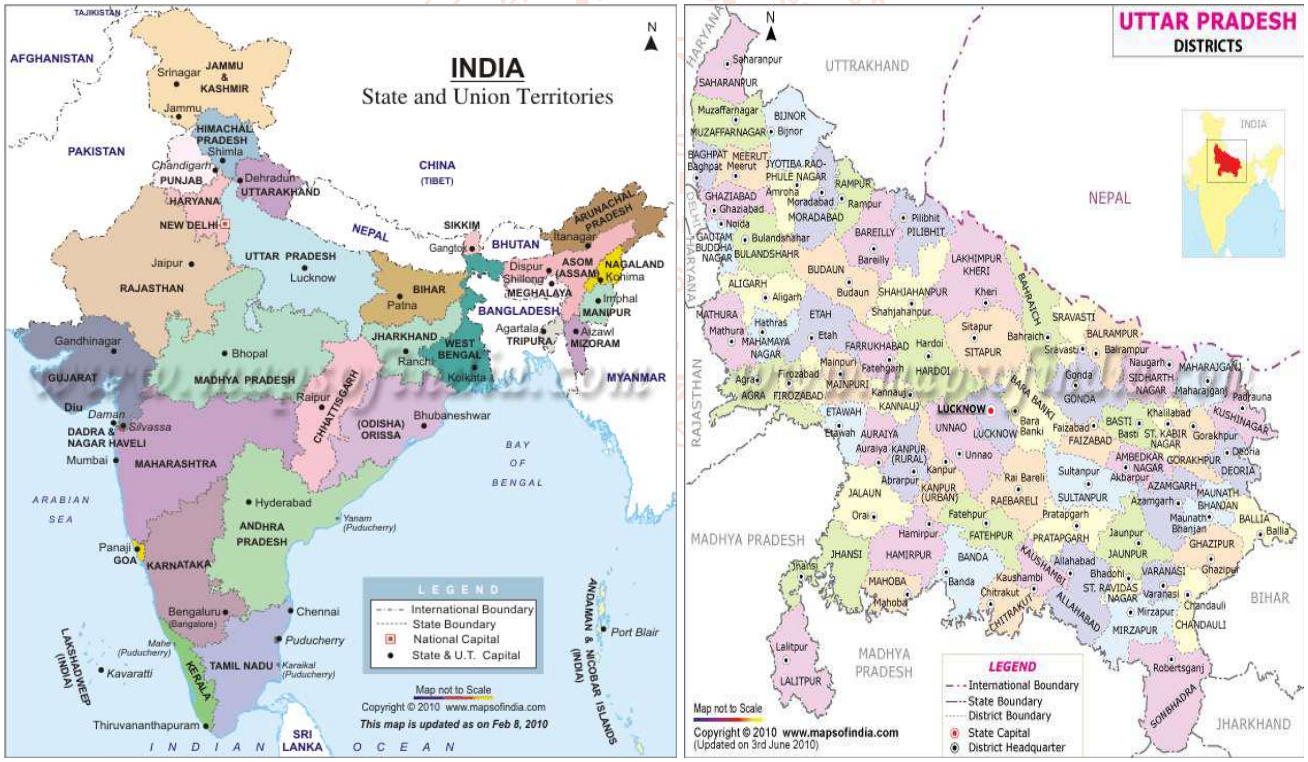
japonica, *Botomus umbellatus*, and *Ranunculus sceleratus* are commonly found in freshwater bodies and are known for their ability to absorb metals in different plant parts including roots, stems, leaves, and flowers.[2]

The Gomti River is one of the important rivers of Uttar Pradesh and passes through the city of Lucknow, where it receives large quantities of domestic sewage, industrial waste, and urban runoff. Rapid population growth and increasing human activities along the river have resulted in serious deterioration of water quality. Various industries such as sugar mills, distilleries, paper mills, fertilizer units, automobile workshops, thermal power plants, and small-scale manufacturing units discharge untreated or partially treated waste into the river. In addition, municipal drains carrying household waste, medical waste, and solid refuse directly enter the river, leading to the accumulation of toxic substances including heavy metals.[3]

Heavy metals present in river water are of particular concern because they persist in the environment for a long time and may enter the food chain through aquatic organisms. Continuous exposure to these metals may affect fish, plants, animals, and ultimately human beings. Therefore, the study of heavy metal accumulation in aquatic plants is important for understanding the level of pollution and for developing natural methods of water purification.[4]

Aquatic plants can be effectively used in phytoremediation, which is an eco-friendly and cost-effective technique for removing pollutants from contaminated water. By absorbing and storing toxic metals in their tissues, these plants help in reducing the concentration of harmful substances in the aquatic environment.[5]

The present study was undertaken to evaluate the level of heavy metal contamination in the Gomti River near Lucknow city and to examine the accumulation capacity of selected aquatic plants with respect to Cadmium (Cd), Copper (Cu), and Arsenic (As). The study also aims to assess the potential use of these plants in phytoremediation for improving the quality of polluted river water.[6]



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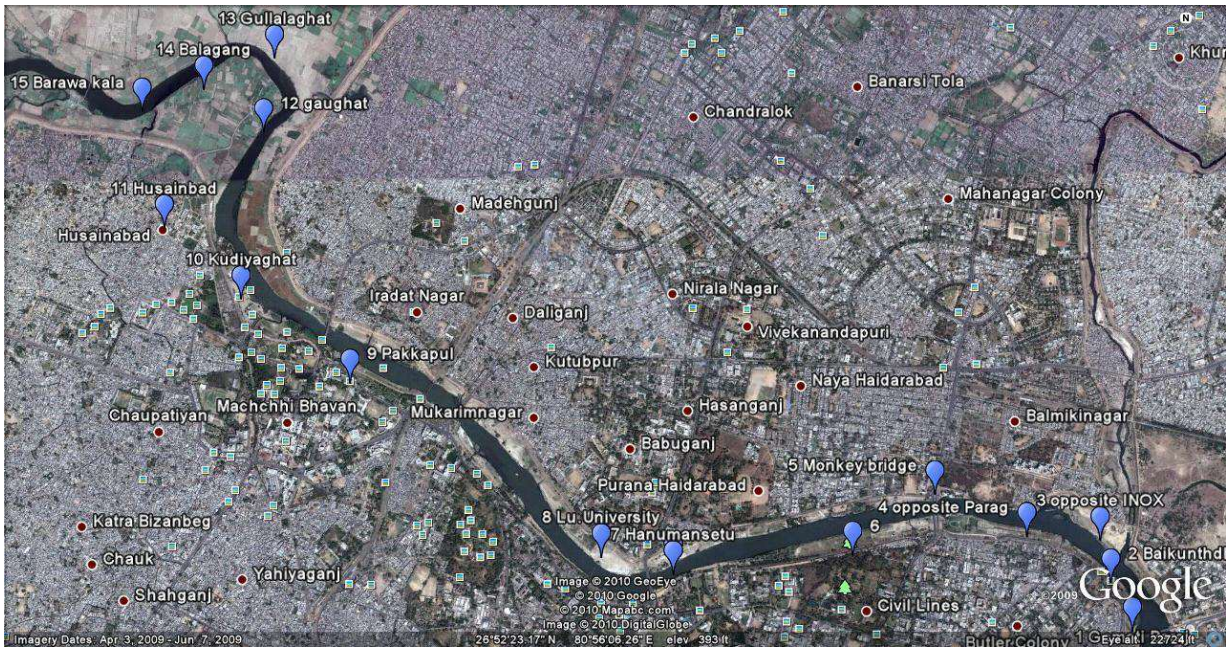

MATERIALS AND METHODS

Study Area

The present study was conducted along the Gomti River flowing through Lucknow city, Uttar Pradesh, India. The Gomti River originates from Gomat Taal near Madhotanda in Pilibhit district and flows through several districts of Uttar Pradesh before joining the Ganga River near Saidpur, Kaithi in Ghazipur district[7]. After flowing for about 240 km, the river enters Lucknow city and passes through densely populated urban areas. In Lucknow, the river receives a large amount of untreated domestic sewage, industrial effluents, and urban runoff through several drains, which significantly affects the quality of river water[8].

Lucknow city lies between latitude 26°30′ to 27°10′ North and longitude 80°30′ to 81°13′ East, at an elevation of about 123 meters above sea level. Due to rapid urbanization and industrialization, the river water in this region is exposed to various pollutants including heavy metals, organic waste, and suspended solids[9].

Table 1: Mean concentration and SD of As, Cd and Cu

Site	H. Verticillata			S. Japonica			B. umbelatus			R. Scleratus		
	As	Cd	Cu	As	Cd	Cu	As	Cd	Cu	As	Cd	Cu
1	0.17± 0.002	0.94± 0.04	1.34± 0.07	0.14± 0.005	1.53± 0.02	1.38± 0.02	0.14± 0.002	0.54± 0.02	1.63± 0.04	0.12± 0.002	0.44± 0.02	1.12± 0.04
2	0.15± 0.003	0.90± 0.04	1.30± 0.06	0.15± 0.004	1.62± 0.02	1.64± 0.04	0.15± 0.002	0.46± 0.02	1.48± 0.11	0.11± 0.003	0.38± 0.05	1.14± 0.04
3	0.17± 0.005	0.72± 0.04	1.16± 0.05	0.13± 0.002	1.34± 0.03	1.62± 0.04	0.15± 0.003	0.48± 0.02	1.38± 0.05	0.11± 0.005	0.36± 0.04	1.24± 0.10
4	0.15± 0.003	0.66± 0.02	1.22± 0.05	0.13± 0.002	1.22± 0.02	1.66± 0.02	0.15± 0.002	0.82± 0.02	1.32± 0.04	0.12± 0.003	0.34± 0.03	1.22± 0.04
5	0.14± 0.007	0.70± 0.07	1.28± 0.05	0.13± 0.005	1.27± 0.02	1.84± 0.07	0.14± 0.001	0.69± 0.01	1.42± 0.05	0.12± 0.007	0.38± 0.04	1.10± 0.05
6	0.14± 0.011	0.76± 0.07	1.40± 0.06	0.14± 0.006	1.22± 0.05	1.65± 0.09	0.15± 0.003	0.48± 0.06	1.36± 0.05	0.10± 0.011	0.28± 0.04	1.60± 0.06
7	0.15± 0.011	0.78± 0.06	1.42± 0.10	0.15± 0.005	1.40± 0.02	2.00± 0.07	0.15± 0.003	0.86± 0.03	2.08± 0.07	0.13± 0.011	0.44± 0.04	1.44± 0.10
8	0.13± 0.005	0.75± 0.01	1.36± 0.02	0.15± 0.002	1.53± 0.04	1.92± 0.02	0.13± 0.003	0.76± 0.04	1.62± 0.07	0.11± 0.006	0.42± 0.06	1.52± 0.05
9	0.14± 0.002	0.70± 0.05	1.38± 0.01	0.13± 0.003	1.51± 0.03	1.74± 0.01	0.14± 0.004	0.72± 0.03	1.68± 0.01	0.12± 0.002	0.36± 0.05	1.42± 0.04

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10	0.13± 0.005	0.58± 0.05	1.98± 0.06	0.13± 0.001	1.44± 0.04	1.92± 0.02	0.15± 0.003	0.70± 0.05	1.70± 0.02	0.12± 0.005	0.32± 0.05	1.32± 0.06
11	0.14± 0.003	0.71± 0.07	1.68± 0.06	0.13± 0.003	1.34± 0.06	1.65± 0.06	0.16± 0.002	0.68± 0.07	1.90± 0.04	0.12± 0.003	0.36± 0.02	1.38± 0.03
12	0.13± 0.002	0.62± 0.04	1.44± 0.05	0.13± 0.002	1.12± 0.03	1.82± 0.09	0.15± 0.003	0.31± 0.02	1.58± 0.03	0.11± 0.002	0.22± 0.02	1.02± 0.05
13	0.13± 0.004	0.78± 0.04	1.44± 0.02	0.13± 0.004	1.14± 0.04	2.08± 0.06	0.15± 0.007	0.36± 0.03	1.34± 0.04	0.11± 0.004	0.32± 0.02	1.26± 0.03
14	0.14± 0.008	0.82± 0.07	1.78± 0.05	0.14± 0.003	1.30± 0.02	1.88± 0.06	0.14± 0.002	0.54± 0.03	2.04± 0.02	0.12± 0.008	0.32± 0.04	1.34± 0.03
15	0.14± 0.002	0.80± 0.05	1.86± 0.05	0.16± 0.004	1.32± 0.03	1.94± 0.03	0.14± 0.002	0.66± 0.04	2.00± 0.03	0.13± 0.004	0.34± 0.03	1.42± 0.10

Table 2:Mean concentrations, standard deviation and range of As, Cd and Cu (µg g−1 dry weight) in complete plants collected from 15 selected sites of Gomti River, Lucknow (U.P.)

Table 2: Mean concentrations, standard deviation and range of As, Cd and Cu (µg g−1 dry weight)

Species	As		Cd		Cu	
	Mean	Range	Mean	Range	Mean	Range
R. sceleratus	0.12±0.007	0.102–0.127	0.35±0.06	0.22–0.44	1.30±0.24	1.02–1.52
H. verticillata	0.14±0.013	0.129–0.172	0.74±0.08	0.70–0.94	1.47±0.24	1.22–1.86
B. umbellatus	0.15±0.007	0.132–0.163	0.60±0.16	0.31–0.86	1.64±0.26	1.32–2.08
S. japonica	0.14±0.006	0.126–0.147	1.35±0.15	1.12–1.62	1.78±0.21	1.38–2.08

For the present investigation, fifteen sampling sites were selected along the Gomti River in and around Lucknow city. Samples were collected from both polluted and relatively clean stretches of the river to compare the level of heavy metal accumulation in aquatic plants.

Collection of Aquatic Plants

Aquatic plant samples were collected from all selected sampling sites during the post-monsoon season. The selected species included *Ranunculus sceleratus*, *Hydrilla verticillata*, *Botomus umbellatus*, and *Sagittaria japonica*. These plants were chosen because they are commonly found in freshwater bodies and are known for their ability to accumulate heavy metals from water and sediments[10].

The collected plants were placed in clean plastic bags and transported to the laboratory for further analysis. All samples were properly labeled according to sampling site and plant species.

Description of Selected Plant Species

Ranunculus sceleratus is an aquatic herbaceous plant commonly found in wet and marshy habitats. It grows in shallow water and moist soil and is widely distributed in Asia, Europe, and North America.

Hydrilla verticillata is a submerged perennial aquatic plant belonging to the family Hydrocharitaceae. It grows in lakes, ponds, rivers, and slow-moving water bodies and is known for its high capacity to absorb dissolved metals from water.

Botomus umbellatus is a perennial aquatic plant belonging to the family Butomaceae. It grows in shallow water and muddy habitats and is often used in ecological studies related to water pollution.

Sagittaria japonica is a perennial aquatic plant growing in wetlands and shallow water bodies. It has ribbon-like leaves and a well-developed root system which helps in absorbing dissolved metals from water and sediments[11].

Sample Preparation and Analysis

All collected plant samples were washed carefully with tap water followed by distilled water to remove dust and attached particles. The cleaned samples were cut into small pieces and dried in an oven at 80°C for 72 hours. The dried samples were ground into fine powder using a mortar and pestle.

About 1 gram of dried plant material was digested using a mixture of concentrated nitric acid (HNO_3) and perchloric acid ($HClO_4$) in a ratio of 3:1. The digestion was continued until a clear solution was obtained. After cooling, the solution was filtered using Whatman filter paper and diluted with distilled water[12].

The concentration of heavy metals such as Cadmium (Cd), Copper (Cu), and Arsenic (As) in the digested

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samples was determined using Atomic Absorption Spectrophotometer (AAS). Blank samples were also analyzed to ensure accuracy of the results. All measurements were taken in triplicate and the average value was used for calculation.

Calculation of Metal Accumulation

Metal accumulation in plant samples was calculated using the following formula:

Metal Concentration (µg/g) = X × V / W

Where,
X = Reading of sample in ppm on AAS
Y = Reading of blank sample in ppm
V = Final volume of digested sample
W = Dry weight of plant sample in grams[13]

This method was used to determine the level of heavy metal accumulation in different aquatic plant species collected from various sites of the Gomti River.

RESULTS

Arsenic (As)

The concentration of arsenic (As) in the selected aquatic plants collected from different sampling sites along the Gomti River showed considerable variation. Among the studied species, *Hydrilla verticillata* showed the highest accumulation of arsenic at one of the highly polluted sampling sites, indicating its strong ability to absorb dissolved metals from water. Moderate accumulation of arsenic was observed in *Sagittaria japonica* and *Botomus umbellatus*, while the lowest concentration was recorded in *Ranunculus sceleratus*. The variation in arsenic concentration among different plants suggests that the metal uptake capacity depends on plant species as well as the level of pollution at the sampling site.

Cadmium (Cd)

Cadmium concentration was detected in all the selected plant samples, but the amount differed significantly among species. The highest concentration of cadmium was found in *Sagittaria japonica*, particularly at the sampling sites receiving domestic sewage and industrial discharge. *Hydrilla verticillata* also showed noticeable accumulation, whereas the lowest cadmium concentration was observed in *Ranunculus sceleratus*. The results indicate that *Sagittaria japonica* is more efficient in absorbing cadmium from polluted water compared to other studied species.

Copper (Cu)

Copper (Cu) was present in all the plant samples collected from different locations of the Gomti River. The highest concentration of copper was recorded in *Botomus umbellatus*, which was collected from sites affected by industrial and urban waste discharge. Moderate levels were observed in *Hydrilla verticillata* and *Sagittaria japonica*, while the lowest concentration of copper was found in *Ranunculus sceleratus*. The results show that *Botomus umbellatus* has a higher capacity to accumulate copper from contaminated water.

DISCUSSION

Heavy metals are naturally present in aquatic ecosystems, but their concentration increases due to human activities such as industrial discharge, domestic sewage, agricultural runoff, and urban waste. When present in excess amounts, these metals become toxic to aquatic organisms and may enter the food chain, causing serious health problems to animals and humans.

The present study shows that the Gomti River in Lucknow city is affected by heavy metal pollution due to continuous discharge of untreated waste. The accumulation of arsenic, cadmium, and copper in aquatic plants indicates the presence of these metals in river water and sediments. Different plant species showed different capacities for metal accumulation, which may be due to differences in root structure, growth habit, and physiological characteristics.

Among the studied plants, *Hydrilla verticillata* showed high accumulation of arsenic, *Sagittaria japonica* accumulated more cadmium, and *Botomus umbellatus* showed higher uptake of copper. These results suggest that aquatic macrophytes can be used as bio-indicators of heavy metal pollution as well as natural agents for removal of toxic metals from water.

Phytoremediation is considered an eco-friendly and cost-effective method for cleaning polluted water bodies. Many aquatic plants such as *Hydrilla*, *Eichhornia*, *Typha*, and *Bacopa* have been reported to accumulate heavy metals in large amounts and are widely used for environmental cleanup. The present study also confirms that selected aquatic plants growing in Gomti River have the potential to remove heavy metals and can be used in water pollution control programs.

CONCLUSION

The present investigation revealed that the Gomti River flowing through Lucknow city is contaminated with heavy metals such as arsenic, cadmium, and copper due to domestic, industrial, and urban waste discharge. The selected aquatic plants showed significant capacity to accumulate these metals from polluted water.

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Among the studied species, *Hydrilla verticillata* was found to be the best accumulator of arsenic, *Sagittaria japonica* showed maximum accumulation of cadmium, and *Botomus umbellatus* accumulated higher concentration of copper. *Ranunculus sceleratus* showed comparatively lower accumulation of metals.

The results indicate that aquatic plants can be effectively used in phytoremediation for removal of heavy metals from polluted river water. Therefore, the use of suitable aquatic macrophytes may help in improving the quality of contaminated water bodies in an economical and environmentally safe way.

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