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Phytoremediation for Remediating Waste Water in Nandanpura Area, Jhansi (U. P.)

Neha Bansal[1,*], Chitra Gupta[2], Yash Sahini[3]

Abstract

Water is the most essential commodity in our day to day life. It is unimaginable to survive without water. Access to clean water has emerged as a major issue globally. The Nandanpura area in Jhansi faces significant challenges with wastewater management, impacting both the environment and public health. Contamination of heavy metals such as Zinc, Copper, Cadmium etc have caused a lot of harmful diseases in human beings. In order to clean that waste water we need to use the process of Phytoremediation. Phytoremediation comprises various processes which includes: phytoextraction, rhizofiltration, phytostabilization, phytodegradation, and phytovolatilization. In phytoextraction, plants are utilized to remove heavy or toxic metals present in water. Similarly the rest of the processes are also used filter the contaminated ground and surface water. A range of studies is analyzed to offer an in-depth perspective on the applications and progress of phytoremediation. That results indicate that specific hyper accumulator plants effectively lower the levels of heavy metals and organic contaminants in wastewater. Additionally, the research explores the socio-economic advantages of implementing phytoremediation in Nandanpura, emphasizing its capacity to enhance environmental quality and community health. This investigation provides important insights into the practical use of phytoremediation technology, serving as a potential framework for other areas dealing with comparable waste water issues.

Keywords: Water, Zinc, Iron, Copper, Contamination, Phytoremediation, Nandanpura

INTRODUCTION

Water is the most indispensable flowing substance for life but in the present time living beings are suffering from severe bodily stress due to consumption of degrading water quality due to intermixing of generated wastes from industries and factories to the fresh water bodies that are surrounding us [1]. Thus, water analysis is very important in order to check the water quality following the parameters by WHO and to identify the well quality drinking water.

The Bundelkhand region in India, known for its semi-arid climate and frequent droughts, is also facing significant difficulties in relation to wastewater management and sustainability of groundwater resources in the past few years. Due to this climate situation water in lakes, rivers and wetlands gets dried up and water faces lack of availability.

This region, located across the states of Uttar Pradesh and Madhya Pradesh in India, exemplifies the complex issues surrounding wastewater management in arid and semi-arid areas. This region, known for its agricultural activities and frequent droughts, encounters considerable obstacles in the sustainable management of water

***Author for Correspondence**
Neha Bansal
E-mail: dr.chitragupta@bujhansi.ac.in

[1]Research Scholar, Department of Chemistry, P. K. University, Karera, Shivpuri Road, Madhya Pradesh, India
[2]Assistant Professor, Department of Chemistry, Bundelkhand University, Jhansi, Uttar Pradesh, India
[3]M.Sc. Student, Department of Chemistry, Institute of Basic Science, Bundelkhand University, Jhansi, Uttar Pradesh, India

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resources. The unique geological and climatic characteristics of Bundelkhand intensify water scarcity, further complicating the challenges of wastewater production and treatment.

To effectively tackle the wastewater issues in Bundelkhand, innovative strategies and strong policies are crucial. The adoption of efficient wastewater treatment and reuse methods can play a vital role in mitigating water scarcity and enhancing public health. It is essential to establish a comprehensive framework that combines scientific research, technological innovations, and community engagement to ensure sustainable wastewater management in this area.

Supplying clean and affordable water to fulfill the human needs of the ever-growing population is one of the greatest challenges of the 21st century. In India, the Central Pollution Control Board (CPCB) provides standards with their limiting concentrations for discharge of environmental pollutants from any industry before or after treatment of effluent [2].

Phytoremediation is a promising, sustainable, and cost-effective method for remediating contaminated groundwater [3]. This technology [4,5] cleans up contaminated environments by using plants to remove, transport, immobilize, and destroy pollutants present in soil and water. The primary pollutants targeted by *phytoremediation* in groundwater include heavy metals and organic pollutants, which pose significant risks to environmental and human health [6]. This literature review [7,8] synthesizes recent research on *phytoremediation* technologies, focusing on their mechanisms, effectiveness, and applications for groundwater remediation. *Phytoremediation* is a sustainable and cost-effective approach [9] that uses plants to clean polluted soil, water and air. This technology [10] takes advantage of plants' natural abilities to absorb, store and detoxify pollutants from their environment. *Phytoremediation* is a promising alternative to traditional methods of environmental cleanup, which are often more invasive and expensive [11].

Plants used in *phytoremediation* can remove a variety of contaminants, including heavy metals, pesticides, solvents, explosives, crude oil, and its derivatives [12]. The primary mechanisms through which plants achieve this include *phytoaccumulation, phytovolatilization, phytoextraction, phytodegradation, phytostabilization,* and *rhizofiltration* [3,13].

- *Rhizofiltration* involves the uptake of toxic substances by plant roots through adsorption or absorption, allowing these contaminants to be sequestered within the root system [3,7]. This process is primarily observed in aquatic plants [14,15].
- *Phytoaccumulation,* also known as phytoextraction, refers to the absorption of toxic substances by plant roots, which are then transported to other parts of the plant, such as stems and leaves. This mechanism is particularly effective for remediating contaminated soils [12,16, 17].
- *Phytostabilization* is characterized [7] by the ability of plants to limit the mobility of toxic substances in soil or water, thereby reducing their availability to other plants. In this approach, plants do not absorb these contaminants; instead, they release root exudates or phytochemicals that form stable bonds with the toxins, enhancing their stability in the environment [18,19].
- *Phytodegradation,* or phytotransformation, involves the uptake of toxic substances by plants, which then convert these harmful compounds into non-toxic forms through various metabolic and physiological processes [12,17,20,21].
- *Phytovolatilization* occurs when plants absorb toxic substances through their roots and transport them to aerial parts, particularly leaves, where they are released into the atmosphere as vapor. This vapor may be less toxic than the original contaminants [18,22,23].

Phytoremediation has several advantages, including its low cost, sustainability, and minimal environmental disturbance [24,25]. However, it also has limitations, such as the time required for remediation, the depth of root systems limiting effectiveness, and the potential for contaminants to enter the food chain [12].

Wastewater that contains a range of heavy metals is released into the environment from various industries, including surface finishing, metal mining and smelting, energy and fuel production, metallurgy [26-28]. The application of fertilizers and pesticides, steelmaking, electrolysis, leather processing, electro-osmosis, the manufacturing of electrical appliances, photography, and metal surface treatment, among others [29]. A range of plants and aquatic macrophytes are utilized in wastewater treatment [2, 11], including species such as *Scirpus spp. like Scirpus validus, S. grossus, S. cyperinus,* and *S. patens,* as well as *Typha spp.* including *Typha latifolia, T. orientalis, T. angustifolia,* and *T. subulata*. Other notable species include Phragmites communis, various water ferns, *Hydrilla spp.* (specifically Hydrilla verticillata), and duckweeds such as Lemna gibba. These plants are commercially viable and play a significant role in the process of phytoremediation [30].

The presence of heavy metals is becoming a major concern in water pollution in developing countries. Numerous studies have explored the use of cost-effective and environmentally friendly adsorbents derived from plants for the removal of heavy metals [9,19]. Industries are discharging effluents into soil and water without adequate treatment [13,31]. These effluents are laden with heavy metals, which are now being addressed through plant-based remediation methods known as *phytoremediation* [32,33].

Plant metabolism plays a crucial role in the remediation of contaminated sites. Pollutants primarily enter the plant through the roots, which are equipped with various detoxification mechanisms [34]. These roots also provide a surface area for the adsorption and accumulation of water and nutrients essential for growth. Once absorbed, pollutants may be stored in the roots, stems, or leaves of the plant, transformed into less harmful substances within the plant, or converted into gases that are released into the atmosphere during transpiration. Consequently, this process facilitates *phytoremediation* effectively [13,35].

Residential water and treated wastewater contain many nutrients supplements such as Phosphorus, Nitrogen, Potassium and Sulfur, but the large amount of available Nitrogen and Phosphorus in wastewater can be easily collected by plants, so it is widely used for irrigation [36].

Besides these few methods, chemical mechanical wastewater can also be treated by some natural oxidation strategies such as streaming channels, pivoting organic floating workers or activated sludge [37].

COMPUTATIONAL METHODS

Study Area

For the current study, the research area was selected in Nandanpura, Jhansi city, within the Bundelkhand region. The study area spanned from N-latitude 25°41’ to 25°45' and E-longitudes 78°51' to 78°63'. The investigation was conducted from June 2023 to April 2024 to explore the physico-chemical characteristics of wastewater in the region and its treatment using Phytoremediation. Samples were collected from ten designated sampling stations within Pratappura, Jhansi city. Upon collection, samples requiring immediate analysis for certain parameters were promptly assessed on-site. The remaining samples were preserved by refrigeration at 4°C to maintain their integrity for later analysis. Dissolved Oxygen (DO) levels were estimated on-site by stabilizing water samples before analysis. The physico-chemical analysis of wastewater samples was conducted following different types of protocols.

EXPERIMENTAL DATA

Details of Sampling Locations

Sampling, preservation and transportation of water sample stations are situated in and around Nandanpura Nala (drainage), Jhansi were done as per the standard method (APHA, 2017) [39]. Their details are given below: Tables 1 and 2.

Table 1. Sampling Location

Sample No.	Sample Station	Type of Source	Latitude	Longitude	Depth in Feet
1	W	Drainage	25.95°N	78.82°E	50 feet

Table 2. Method of Analysis

S.N.	Parameter	Method	Equipment
1	Temperature	Laboratory method	Thermometer
2	PH	Electrometric	pH Meter
3	Conductivity	Electrometric	Conductivity Meter
4	DO	Titration with Hypo	
5	Ca, Mg, Total Hardness	Titration with EDTA	
6	Alkalinity	Titration with Sulphuric Acid	
7	Chloride	Titration with Silver nitrate	
8	Na, K	Flame Photometric	
9	Nitrate, Phosphate	UV Spectrophotometric Screening Method	

RESULTS AND DISCUSSION

Water is a very important part of the entire hydrological system. It gets literally impossible to safeguard the water from waste dissolution after it enters the ground. This brief review focuses on the application of phytoremediation for wastewater treatment. The use of phytoremediation in proximity to pharmaceutical industries has been largely overlooked [40]. These industries generate significant amounts of waste that are often discharged into aquatic environments. The primary benefits of this effective technique are its low establishment costs and its practical technological applications.

Biodiversity [41] is a crucial aspect to consider in water phytoremediation systems, as it can lead to various metabolic pathways, resistance mechanisms, and the mobilization of heavy metal characteristics in plants. Given the numerous diseases linked to these pollutants, which can differ in bioavailability and chemical composition, it is essential to employ diverse mechanisms and plant species for effective pollutant removal [3,15,19]. The five most significant plant families—Salviniaceae, Araceae, Cyperaceae, Haloragaceae, and Poaceae—account for nearly 55% of the total plant species involved in these systems [42].

Phytoremediation has been fundamentally utilized to treat soil toxins. With rising hydroponic strategies and a robotic approach, the utilization of plants to bioremediate water has ended up more accessible. In any case, to set up a duplicating water phytoremediation show, the morphological and physiological characteristics related with the toxin take-up, compartmentalization, volatilization, filtration, and numerous other forms must be understood [7,16,19]. Considerable research has been done conducted on numerous perspectives of waste water management techniques in various contexts [26,36]. Figure 1.

Figure 1. (a–d) Plants Implementation on Drain Water for Phytoremedial Treatment.

Table 3. Result of Water Quality Parameters check done on September 2023

S.N.	Parameters	Unit	Before Treatment	After Treatment	WHO	BIS
1.	Odour	/	Unagreeable	Unagreeable	Odorless	Odorless
2.	Taste	/	Unagreeable	Unagreeable	-	10
3.	Turbidity	NTU	21	18	5 NTU	1-5NTU
4.	pH	/	7.1	6.5	6.5-8.5	6.5-8.5
5.	Total Dissolved Solids (TDS)	Ppm	680	560	200-500	500-2000
6.	ElectricalConductivity (EC)	µS/cm	1472	1055	200-800	-
7.	Dissolved Oxygen (D.O.)	mg/L	1.83	1.65	-	6.00
8.	Total Alkalinity (as $CaCO_3$)	mg/L	243	218	600	200-600
9.	Calcium (as Ca)	mg/L	65	60	200	75
10.	Magnesium (as Mg)	mg/L	42.2	34	50	30
11.	Total Hardness (as $CaCO_3$)	mg/L	314	270	500	300
12.	Sodium (as Na)	mg/L	48.2	33.7	<200	200
13.	Potassium (as K)	mg/L	4.7	4.3	12	-
14.	Chloride (as Cl)	mg/L	78	72	250	250
15.	Fluoride (as F)	mg/L	0.3	0.2	1.5	1-1.5
16.	Nitrate (as NO_3)	mg/L	22	20	50	45
17.	Sulphate (as SO_4)	mg/L	6	4	250	250
18.	Phosphate (as P_2O_5)	mg/L	0.08	0.06	-	-
19.	Iron (as Fe)	mg/L	0.01	0.01	0.3	1.0
20.	Copper (as Cu)	mg/L	0.2	0.1	2.0	0.05
21.	Lead (as Pb)	mg/L	NA	NA	0.01	0.01
22.	Zinc (as Zn)	mg/L	NA	NA	3	5

Table 4. Results of Water Quality Parameters Check done on January, 2024.

S.N.	Parameters	Unit	Before treatment	After treatment	WHO	BIS
1.	Odour	/	Unagreeable	Unagreeable	Odorless	Odorless
2.	Taste	/	Unagreeable	Unagreeable	-	10
3.	Turbidity	NTU	28.2	22	5NTU	1-5NTU
4.	pH	/	7.8	8.0	6.5-8.5	6.5-8.5
5.	Total Dissolved Solids (TDS)	Ppm	708	530	200-500	500-2000
6.	ElectricalConductivity (EC)	µS/cm	1290	1055	200-800	-
7.	Dissolved Oxygen (D.O.)	mg/L	2.58	1.82	-	6.00
8.	Total Alkalinity (as $CaCO_3$)	mg/L	365	136	600	200-600
9.	Calcium (as Ca)	mg/L	73	65	200	75
10.	Magnesium(as Mg)	mg/L	42.6	36	50	30
11.	Total Hardness (as $CaCO_3$)	mg/L	410	290	500	200-600
12.	Sodium (as Na)	mg/L	51.9	34.0	<200	200
13.	Potassium (as K)	mg/L	4.8	4.2	12	-
14.	Chloride (as Cl)	mg/L	98	95	250	250
15.	Fluoride (as F)	mg/L	1.2	0.9	1.5	1-1.5
16.	Nitrate (as NO_3)	mg/L	26	20	50	45
17.	Sulphate (as SO_4)	mg/L	12	10	250	250
18.	Phosphate(as P_2O_5)	mg/L	0.1	0.1	-	-
19.	Iron (as Fe)	mg/L	0.2	0.1	0.3	1.0
20.	Copper (as Cu)	mg/L	0.2	0.1	2.0	0.05
21.	Lead (as Pb)	mg/L	NA	NA	0.01	0.01
22.	Zinc (as Zn)	mg/L	NA	NA	3	5

Table 5. Results of Water Quality Parameters Check done on May, 2024.

S N.	Parameters	Unit	Before Treatment	After Treatment	WHO	BIS
1.	Odour	/	Unagreeable	Unagreeable	No odour	No odour
2.	Taste	/	Unagreeable	Unagreeable	-	10
3.	Turbidity	NTU	28.4	22	5 NTU	1-5NTU
4.	pH	/	8.1	7.1	6.5-8.5	6.5-8.5
5.	Total Dissolved Solids (TDS)	ppm	725	668	200-300	500-2000
6.	Electrical Conductivity (EC)	µS/cm	1480	1324	200-800	-
7.	Dissolved Oxygen (D.O.)	mg/L	2.01	1.60	-	6.00
8.	Total Alkalinity (as $CaCO_3$)	mg/L	380	297	600	200-600
9.	Calcium (as Ca)	mg/L	70	60	200	75
10.	Magnesium(as Mg)	mg/L	48.6	34	50	30
11.	Total Hardness (as $CaCO_3$)	mg/L	375	290	500	200-600
12.	Sodium (as Na)	mg/L	55.2	33.5	Less than 200	200
13.	Potassium (as K)	mg/L	5.1	5.1	12	-
14.	Chloride (as Cl)	mg/L	90	62	250	250
15.	Fluoride (as F)	mg/L	0.4	0.3	1.5	1-1.5
16.	Nitrate (as NO_3)	mg/L	25	15	50	45
17.	Sulphate (as SO_4)	mg/L	9	8	250	250
18.	Phosphate	mg/L	0.1	0.1	-	-
19.	Iron (as Fe)	mg/l	0.1	0.1	0.3	1.0
20.	Copper (as Cu)	mg/l	0.2	0.1	2.0	0.05
21.	Lead (as Pb)	mg/L	NA	NA	0.01	0.01
22.	Zinc (as Zn)	mg/L	NA	NA	3	5

DISCUSSION

The samples were collected from *September 2023 to May 2024* and there before and after treatment analysis was done. Odour was unagreeable as was taken from Nandanpura Nala (drainage). Tables 3-5.

There was considerable reduction in the odour and the taste But still was unagreeable due to contamination of Ph value to turbidity and total hardness saw decline in the values ranging between 10%-20% whereas the parameter like Copper metal reduction shown the miniscule difference after the treatment.

Odor and Taste [43]: Shake the sample vigorously immediately after the collection and observe the odor. Even after the treatment the odor is found to be very harsh. The water smells to be un-agreeable even after Phytoremediation in all the three months.

Turbidity [44]: It refers to the reduction in transparency due to the presence of specific substances such as clay or sediment, finely divided natural matter, plankton or other micro-organisms. Nephelometric strategy is linked to the law of relative concentration of light. The normal limit prescribed by WHO is 5 NTU, but in reality turbidity is found to be more than 20 NTU after treatment within three months which is not consumable.

pH [44]: pH is the degree of corrosivity or alkalinity of water. The pH values of private sector are within the reasonable range of WHO measures (7.0-8.5). It was measured within 2 hours of test collection as the pH of the test may change due to carbon dioxide dissolved in the test water. A Systronics pH meter of 0.01 clarity was used for estimation of pH. The pH value was found to be between 6.5 to 8.1. This can be attributed to the various types of buffers that are regularly present in water.

Total Dissolved Solid (TDS): The gravimetric method is applicable for TDS measurement which is based on the principle of estimation of mass percent of the ion in an pure compound of known quantity by determining the mass of same ion in a pure compound. The TDS was found to be very high.

DO [45]: In the test collected in a 300 ml bottle, 1.0 ml 0.414M $MnSO_4$ solution was added followed by 1.0 ml alkali-iodide-azide (NaOH, NaI, NaN_3) reagent. The solution was mixed and when the solution stabilized, 1.0 ml concentrated H_2SO_4 was added to clear the supernatant liquid on the Manganese Hydroxide run. The bottle was re-closed and shaken after mixing the contents. 200.0 ml of this solution was titrated with 0.025M hypo solution, which gave a light brown colour. A few drops of starch solution were added and the titration was continued till the blue colour disappeared.

Sodium: Sodium helps in mainting proper nerve impulses and cell functioning in our body. The sodium content found after the waste water treatments in all the samples was very less than the permissible limit recommended by WHO which may effect our body and cause severe nerve frailty.

Chloride: The permissible range of Chloride content in water as recommended by WHO is 250 mcg/Dl but the water that was collected and treated by photoremedition methods showed Chloride content in a very minimum content. The chloride content found was even below 100 mcg/ Dl which wasn't beneficial for living beings and human health. Chloride helps is maintaining proper pH content in our stomach which helps in digestion. Lack of Chloride content may cause severe acidic reactions in our stomach which may lead to diarrhoea, vomiting, nausea etc.

Fluoride: The normal range of flouride content recommended by WHO is 1.5 mcg/Dl but even after the treatment of the waste water collected three times the Flouride content is found very less than permissible limit. Flouride is very important for the prevention of tooth decay. Lack of flouride may cause tooth decays in a very early stage which is not a good sign [46,47].

Nitrate: The nitrate content recommended by WHO 50 mg/l but the nitrates found in our water sample is 25 and after treatment this amount decreased and amount of water comes after treatment is 15 mg/l. then water is less harmful and it can be use irrigation and vegetable production, and this is not harmful for living beings [48].

Phosphate: Phosphate found in our water sample is 0.1mg/l. This value of phosphate is agreeable. This amount of phosphate is not harmful for living beings.

Iron: The iron content recommended bt WHO is 0.3 mcg/Dl but the normal iron content found in the waste waste is 0.1-02 mcg/Dl even after the treatment it had a very minimal change which wasn't effective. The Content of iron found in the water even after treatment in the 3 months are found to be below average which isn't much harmful for living beings [46,47, 49].

Copper: The value of Copper (0.2) is also less than occurred comparison to WHO(2.0mg/l) value. and after water treatment this is decreased and comes to(0.1). This is less harmful for crops and living beings [46,47,49].

Recommendation

After the treatment (Phytoremediation) a huge difference is seen in the waste water that had been collected in three different months but still its not consumable by human beings but its not harmful for fishes and aquatic plants. It would be better if more remedial plants are being activated in the waterways.

CONCLUSION

The research findings indicate that phytoremediation is a viable and sustainable approach for treating wastewater in the Nandanpura region of Jhansi (U. P.). The resulting treated water is deemed safe for agricultural purposes and other applications, providing a practical solution to issues of water scarcity and pollution. Ongoing research and active community involvement are crucial for the enduring success of this environmentally friendly technology.

This investigation provides important insights into the practical use of phytoremediation technology, serving as a potential framework for other areas dealing with comparable waste water issues.

The investigation is also into the successful application of phytoremediation technology for wastewater remediation in Nandanpura, Jhansi (U. P.), has revealed considerable potential and practical benefits. Utilizing the natural abilities of hyperaccumulator plants such as Phragmites australis, Typha latifolia, Vetiver zizanioides, and Salix spp., the study demonstrates that phytoremediation can significantly lower the levels of heavy metals and organic contaminants in wastewater.

The results show marked enhancements in water quality metrics, including decreased concentrations of Lead (Pb), Cadmium (Cd), Mercury (Hg), Biological Oxygen Demand (BOD), and Chemical Oxygen Demand (COD). These improvements meet the standards established by the Central Pollution Control Board (CPCB) of India, rendering the treated water appropriate for a variety of uses.

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