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Phytoremediation of Arsenic Contaminated Wastewater using *Syngonium podophyllum* in a Constructed Wetland System

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Abstract

Arsenic contamination of wastewater poses a serious environmental and public health challenge due to its toxicity, persistence, and bioaccumulative nature. Conventional arsenic removal technologies are often costly, energy-intensive, and generate secondary pollutants, limiting their applicability in developing regions. The present study evaluates the phytoremediation potential of the terrestrial ornamental plant *Syngonium podophyllum* for arsenic removal from contaminated wastewater using a laboratory-scale constructed wetland (CW) system. Synthetic wastewater containing arsenic at concentrations of 5, 10, 15, 20, and 25 mg/L^{-1} was treated over 25 days, and the removal efficiency was monitored at regular intervals. Results indicated an apparent time-dependent increase in arsenic removal, with maximum efficiency (93.33%) observed at an initial concentration of 5 $mg\ L^{-1}$ after 25 days. Removal efficiency declined with increasing arsenic concentration, suggesting concentration-dependent inhibition of phytoremediation. One-way ANOVA confirmed a statistically significant effect of initial arsenic concentration on removal efficiency ($p < 0.001$). Bioaccumulation analysis revealed tissue-specific arsenic distribution following the order root > shoot > leaf, indicating limited translocation to aerial parts. The findings demonstrate that *S. podophyllum* is a practical, low-cost, and environmentally sustainable bio-agent for arsenic phytoremediation in constructed wetlands, particularly under low to moderate levels of contamination.

Keywords: Arsenic remediation; Phytoremediation; Constructed wetland; *Syngonium podophyllum*; Heavy metals; Wastewater treatment

Introduction

Rapid industrial and agricultural expansion has led to widespread contamination of water resources with heavy metals, creating significant risks for environmental stability and public health (Ali et al., 2013; Madjar and Vasile, 2025). Among these metals, arsenic is particularly concerning due to its high toxicity, long-term persistence, and tendency to accumulate in the food chain (Arora et al., 2008; Ghosh and Singh, 2005; Uddin et al., 2021). Arsenic enters water systems through natural processes, such as rock weathering, and human activities, including mining, smelting, and the use of arsenic-based pesticides (Wuana and Okieimen, 2011; Modaihsh et al., 2004; Genchi et al., 2022). Long-term exposure, even at low levels, is linked to severe health problems, including skin lesions, cardiovascular disease, and various cancers (Mudipalli, 2008; Kara, 2005; Martínez-Castillo et al., 2021). Traditional arsenic-removal techniques, such as chemical precipitation, ion exchange, and membrane filtration, are often costly, energy-intensive, and may produce toxic sludge (Prasad, 2003; Van Aken, 2009; Rahidul, 2023). These limitations drive the need for affordable, environmentally sound alternatives, especially in developing regions.

Phytoremediation has emerged as a viable solution, using plants to clean up contaminated soil and water in a cost-effective and ecologically gentle manner (Clemens, 2001; Garbisu and Alkorta, 2003; Park and Oh, 2023). Plants can absorb, concentrate, and stabilize pollutants, reducing environmental harm while preserving soil and water quality (Suresh and Ravishankar, 2004; Chehregani and Malayeri, 2007; Zaman et al., 2024). This solar-powered approach is gaining attention for its low environmental impact, visual appeal, and economic benefits compared to conventional engineering methods (Van Aken, 2009; Vijayan et al., 2023).

Constructed wetlands (CWs) are engineered systems that mimic natural wetlands, treating wastewater through a combination of physical, chemical, and biological processes, including sedimentation, adsorption, microbial activity, and plant uptake (Brix et al., 2007; Vymazal, 2009; Rosendo et al., 2022). A key factor in their success is selecting plant species that can tolerate contamination while effectively absorbing and storing metals (Ghosh and Singh, 2005; Bindu et al., 2010; Ullah et al., 2023). *Syngonium podophyllum*, a fast-growing terrestrial ornamental plant, shows adaptability to wet conditions and potential tolerance to heavy metals. Although several aquatic plants have been studied for phytoremediation, little is known about *S. podophyllum* ability to remove arsenic under constructed wetland conditions (Bindu et al., 2010; Ali et al., 2013; Yue et al., 2021).

Research Gap

Existing research has well documented the ability of aquatic and wetland plants such as water hyacinth (*Eichhornia crassipes*), water lettuce (*Pistia stratiotes*), and cattails (*Typha spp*.) to remove heavy metals in constructed wetlands (Ghosh and Singh, 2005; Brix et al., 2007; Bindu et al., 2010; Wang et al., 2021). These studies confirm that wetland systems can effectively reduce metal loads through plant uptake and associated processes. However, most previous work has focused on naturally aquatic or semi-aquatic species. The potential of terrestrial ornamental plants, intentionally adapted to waterlogged conditions, remains underexplored. In particular, there is limited documented evidence on the use of *Syngonium podophyllum* for arsenic remediation in constructed wetlands, despite its rapid growth, extensive root system, and adaptability to humid environments (Ali et al., 2013).

Moreover, many studies report overall removal efficiencies without detailed analysis of metal distribution within plant tissues or robust statistical validation across a range of concentrations and exposure times. There is a lack of systematic, statistically supported investigations into arsenic removal under controlled concentration gradients using constructed wetlands (Vymazal, 2009; Wuana and Okieimen, 2011; Bravo and Lizama, 2024). This study addresses the gap by evaluating the arsenic phytoremediation capability of *S. podophyllum* in a constructed wetland setup, with an emphasis on concentration-dependent removal, tissue-specific accumulation, and statistical verification of the results.

Material and Methods

Plant Selection and Acclimatization

Healthy *Syngonium podophyllum* plants, measuring 30-40 cm in height, were sourced locally for this study. This fast-growing ornamental plant belongs to the Araceae family and was selected for its adaptability to aquatic environments, extensive root system, and resilience to environmental stresses, making it an ideal candidate for arsenic phytoremediation. To ensure the plants were in optimal condition, those with a height of approximately 30-45 cm and robust biomass were carefully washed with tap water, then with distilled water, to remove any stuck soil particles and debris. The acclimatisation process was conducted under controlled laboratory conditions. Initially, the plants were placed in distilled water for five days, followed by an additional seven days in a Hoagland nutrient solution. This acclimatisation period was essential to confirm the physiological stability of the plants before they were exposed to arsenic-contaminated wastewater, following the guidelines set by Hoagland and Arnon (1950).

Preparation of Synthetic Wastewater

The growth medium used to prepare synthetic wastewater was Hoagland nutrient solution, which contained the macro- and micronutrients required for plant survival and growth. To achieve five concentrations of arsenic (5, 10, 15, 20, and 25 mg L^{-1}), Arsenic was added to the nutrient solution in the form of a soluble arsenic salt. A control system that was not contaminated with arsenic was also maintained. All solutions were prepared with distilled water, and the pH was maintained at a neutral level (pH 6.5-7.0) throughout the experiment.

Experiments on phytoremediation were conducted in a laboratory-scale constructed wetland (CW) system (Fig. 1). The dimensions of the five glass tanks used were 45 cm × 30 cm × 40 cm (length, width, and depth). A support system was used to suspend the plants, leaving only the root parts submerged in the wastewater, with the shoots and leaves above the water. This arrangement reduced foliar pollution and modelled wetlands. The number of acclimated plants was the same in each tank, and the tank was filled with synthetic wastewater of the desired arsenic concentration. The systems were held at ambient laboratory conditions using stagnant water. Sampling was conducted after 5 days and continued through the end of the 25-day experiment. After sampling, an equal volume of distilled water was added to maintain a constant water-to-plant ratio (Vymazal, 2009).

Constructed Wetland Experimental Setup

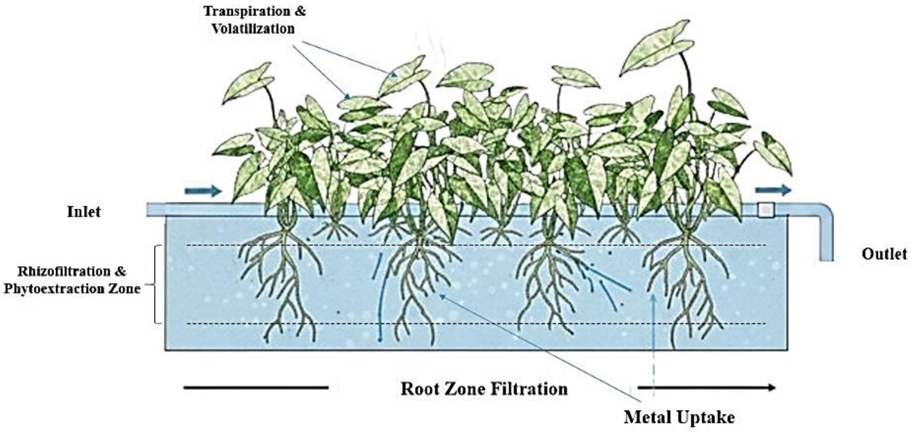

Fig. 1: Shows the Experimental Setup of the Constructed Wetland

Sampling and Analytical Methods

Water samples were collected after specified intervals (5, 10, 15, 20, and 25 days) from each constructed wetland unit and filtered before analysis. Standard analytical techniques were employed to determine the arsenic content in the water samples, as recommended by the American Public Health Association (APHA, 2005). Plants were harvested at the end of the experimental period and divided into roots, shoots, and leaves. The plant samples were washed, dried in an oven at 60 70 °C until constant weight, and finely powdered. Dried plant material was digested with acid, and conventional methods for analysing heavy metals were used to measure arsenic accumulation in various plant parts (APHA, 2005).

Evaluation of Phytoremediation Efficiency

The percentage removal of arsenic from wastewater was calculated using the following equation:

$$Removal\ (\%) = \frac{C_i - C_f}{C_i}\ x\ 100$$

Where Ci is the initial arsenic concentration, and Cf is the final arsenic concentration after treatment. Bioaccumulation of arsenic in plant tissues was expressed as micrograms of metal per milligram of dry plant weight (µg mg^{-1}). The accumulation pattern in root, shoot, and leaf tissues was used to evaluate metal translocation behaviour.

Statistical Analysis

Each experiment was performed in duplicate, and the data are presented as mean ± SD. One-way analysis of variance (ANOVA) was used to determine significant differences in arsenic removal and accumulation efficiency across varying concentrations. The Honest Significant Difference (HSD) test was used to determine the difference between the treatment pair means at the 95% confidence level ($p < 0.05$), as provided by Post hoc Tukey. The statistical analysis was performed using standard statistical programs (Ghosh and Singh, 2005).

Results

Arsenic Removal Efficiency Using a Constructed Wetland

The effectiveness of *Syngonium podophyllum* in treating arsenic-contaminated wastewater was tested using an established constructed wetland (CW) unit at various initial arsenic concentrations (5, 10, 15, 20, and 25 mg L^{-1}) over a 25-day treatment period. The findings showed that there was a time-related enhancement in arsenic removal efficiency, and that a higher initial concentration led to a relatively lower removal percentage. Arsenic removal increased by up to 93.33% on day 25, from a starting concentration of 5 mg L^{-1} to a final concentration of 53.24%. On the same note, the removal efficiency increased from 10 mg $^{L-1}$ to 86.33% during that period. Nonetheless, when the concentration was high enough, such as 25 mgL^{-1}, arsenic removal was low, with 26.53% on day 5 and 46.33% on day 25, indicating that high arsenic levels inhibited phytoremediation efficiency. In general, the findings suggest that the developed system of wetlands favours the efficient removal of arsenic, with the most efficient removals occurring at lower concentrations and more extended exposure periods. Table 1 presents the percentage of arsenic removal at various arsenic levels and at different intervals. In contrast, Fig. 2 illustrates the trend in arsenic removal over time under the same CW conditions.

Fan et al. (2021) reported that pilot-scale vertical flow constructed wetlands achieved mean arsenic removal efficiencies of approximately 40–53%, with improved performance at lower influent concentrations and a strong dependence on temperature. In contrast, horizontal subsurface flow constructed wetlands demonstrated exceptionally high arsenic removal efficiencies (>96%) from highly acidic waters, where pollutant retention was primarily mediated by the wetland media rather than plant uptake (Lizama-Allende et al., 2021). Irshad et al. (2021)

further showed that hybrid vertical subsurface flow wetlands amended with a biochar–microbe composite achieved up to ~95% arsenic removal, substantially outperforming non-amended systems (~55%) through combined biosorption and enhanced phytoextraction mechanisms. Zhou et al. (2023) demonstrated that a *Syngonium podophyllum* endophyte symbiotic system effectively removed low-level uranium from wastewater, reducing influent concentrations (0.5–2.0 mg L^{-1}) to below 0.05 mg L^{-1} within 25 days, with uranium accumulation occurring mainly in plant roots. Aquatic and semi-aquatic weeds such as *Typha*, *Arundo*, *Eichhornia*, *Pistia*, *Lemna*, and *Hydrilla* exhibit strong arsenic uptake and tolerance, supporting phytoremediation as a cost-effective and sustainable option for arsenic-contaminated waters (Roy et al., 2021). Rahman et al. (2025) reported that *Pennisetum purpureum* showed high phytoremediation potential in pilot-scale constructed wetlands, achieving complete removal of bioavailable arsenic at lower contamination levels and accumulating up to 5733 mg kg^{-1} DW in plant tissues, despite phytotoxic effects at higher concentrations.

Hydroponic phytoremediation using the nutrient film technique effectively reduced nitrate-nitrogen in contaminated wastewater, with *Epipremnum aureum* and *Syngonium podophyllum* achieving high removal efficiencies (≈70–90%) and notable BOD_5 reductions (Rajalakshmi and Gunasekaran, 2024). Decorative and ornamental plants contribute significantly to sustainable remediation by combining aesthetic value with the ability to absorb, accumulate, and translocate pollutants from soil, water, and air, thereby supporting ecological restoration and urban environmental quality (Kaur et al., 2025). Phytoremediation is a multidimensional, sustainable approach for treating refractory organic and inorganic pollutants across solid, liquid, and gaseous phases through plant–microbe interactions (Agrawal and Verma, 2021). Chhimwal and Srivastava (2023) demonstrated that a synergistic *Syngonium podophyllum–Trichoderma harzianum* system markedly enhanced industrial wastewater treatment, achieving high removal efficiencies for COD, BOD, nitrate, and lead within six days. Similarly, aquaponic systems have been shown to improve nutrient recycling from aquaculture wastewater, with *Epipremnum aureum* achieving high nitrate-nitrogen and BOD removal efficiencies (Kankia et al., 2024).

Indoor phytoremediation using potted plants, green walls, and plant–microbe systems has also been widely reported as an eco-friendly strategy for reducing indoor air pollutants such as $PM_{2.5}$ and VOCs (Teiri et al., 2022). A bibliometric analysis further revealed a growing research focus on multi-plant symbiotic systems, emphasising their enhanced remediation efficiency through increased plant diversity, soil enzyme activity, and microbial interactions (Song et al., 2023).

Table 1. Percent removal of arsenic from wastewater using the constructed wetland system

Days	5 mg L^{-1}	10 mg L^{-1}	15 mg L^{-1}	20 mg L^{-1}	25 mg L^{-1}
5	53.24	49.33	36.33	29.81	26.53
10	82.33	63.48	44.95	37.88	35.11
15	89.33	74.88	53.91	49.99	41.39
20	92.41	84.96	62.11	57.88	44.88
25	93.33	86.33	67.81	61.33	46.33

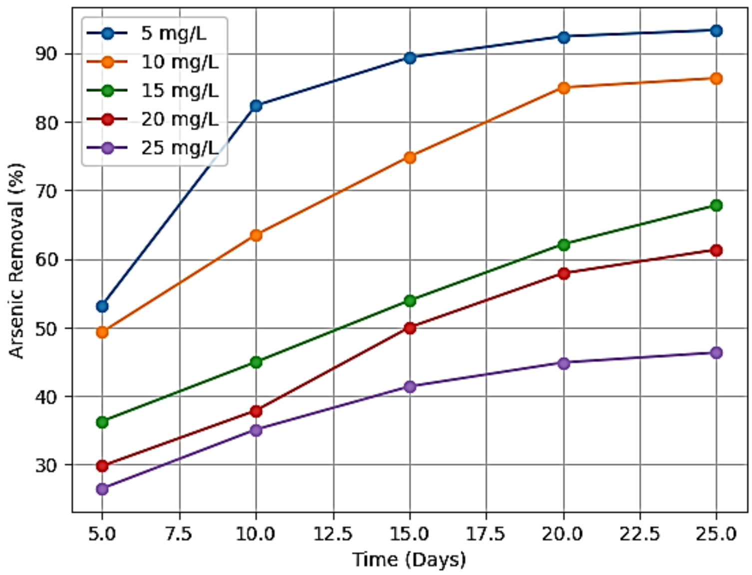

Fig. 2. Percentage Removal of Arsenic over Time Using CW System

Statistical Evaluation of Arsenic Removal

Descriptive statistical analysis indicated that arsenic removal efficiency declined with increasing initial concentration, from 82.13% at the beginning to 38.85% at the end of the experiment. The one-way ANOVA at the

95% confidence level revealed a statistically significant difference in arsenic removal across concentrations ($F = 8.59$, $p < 0.001$). This demonstrates that the initial arsenic level significantly affected the performance of the remediation system developed in the wetland. The post hoc Tukey HSD analysis revealed significant differences between 5 mg L^{-1} and above (15, 20, and 25 mg L^{-1}) and between 10 mg L^{-1} and 25 mg L^{-1}; differences between intermediate concentrations were not significant.

Table 2. Descriptive statistics and ANOVA results for arsenic removal efficiency (%)

Concentration (mg L^{-1})	Mean (%)	SD
5	82.13	16.72
10	71.80	15.56
15	53.02	12.71
20	47.38	13.33
25	38.85	8.13

Accumulation of Arsenic in Plant Tissues

Through accumulation analysis, arsenic uptake in *Syngonium podophyllum* showed a steady, tissue-specific pattern across all treatments. Roots showed the most significant accumulation, with leaves and shoots coming second and third, respectively (Root > Shoot > Leaf). The highest arsenic concentration was 3926.41 µg mg^{-1} in root, 248.99 µg mg^{-1} in shoots and 42.30 µg mg^{-1} in leaves at the initial concentration of 25 mg L^{-1} of arsenic. There was increased arsenic accumulation across all parts of the plant, accompanied by a rise in wastewater arsenic concentration. This selective retention in roots suggests limited translocation of arsenic to aerial tissues, implying that phytostabilisation is the primary remediation process. Table 3 presents the accumulation of arsenic in different plant tissues, and Fig. 3 illustrates the distribution pattern.

Table 3. Accumulation of arsenic in different plant parts using CW system (µg mg^{-1} dry weight)

Concentration (mg L^{-1})	Root	Shoot	Leaf
5	1862.15	116.26	16.42
10	2642.89	138.42	21.29
15	3102.89	186.11	30.42
20	3621.33	219.34	38.63
25	3926.41	248.99	42.30

Note: Values expressed as µg mg^{-1} dry weight

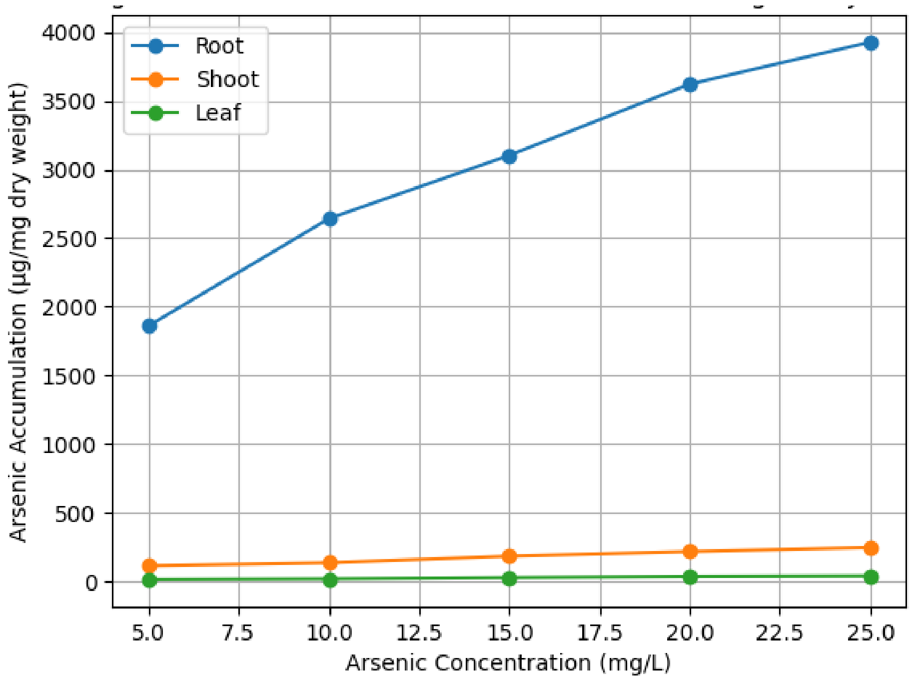

Fig. 3. Arsenic Accumulation in Plant Parts Using CW System

Statistical Analysis of Arsenic Accumulation

The analysis using one-way ANOVA revealed a highly significant difference in arsenic accumulation among roots, shoots, and leaves ($F = 63.87$, $p < 0.001$). The accumulation values were averaged at 3031.04 µg mg^{-1} in roots, 181.82 µg mg^{-1} in shoots, and 29.81 µg mg^{-1} in leaves, which validated the presence of tissue-specific uptake behaviour.

The limited flow of arsenic from the roots to the aerial regions minimises the risk of metal entering the food chain. It improves the environmental safety of the constructed wetland-based phytoremediation system.

Discussion

The current experiment has demonstrated that *Syngonium podophyllum* in a constructed wetland (CW) system is effective at removing arsenic from contaminated wastewater. These findings indicate that the longer the treatment duration, the higher the removal efficiency; conversely, the higher the initial arsenic level, the lower the removal efficiency. This concentration-dependent and time-dependent action is in agreement with the previous phytoremediation studies conducted using heavy metals (Ghosh and Singh, 2005; Ali et al., 2013). The high removal efficiency at low levels of arsenic, particularly the maximum removal of 93.33% at 5 mg L^{-1}, may be attributed to the plant's increased tolerance to the metal at lower concentrations. The metal toxicity at high levels of arsenic likely prevented the metabolic activity of the roots and decreased the uptake efficiency, resulting in poor remediation performance. The ability of high metal concentrations to inhibit the uptake mechanisms of Colocasia esculenta and Zea mays, among other plants with wetland habitats, has been reported to have similar inhibitory effects (Bindu et al., 2010; Gupta et al., 2009).

The statistical analysis also supported the fact that the initial arsenic concentration had a significant effect on removal efficiency, as indicated by the result of one-way ANOVA. A significant variation exists between the treatments of low and high concentrations, indicating the importance of the optimal contaminant load for conducting a successful phytoremediation process. Similar statistically significant data have been documented for constructed wetland-based remediation systems treating arsenic- and cadmium-impacted effluent (Vymazal, 2009; Wuana and Okieimen, 2011). In the accumulation studies, a specific pattern of tissue-specific uptake was observed, whereby arsenic was primarily concentrated in the root, followed by the shoot and leaf (Root > Shoot > Leaf). This accumulation selectivity in roots implies low translocation of arsenic to aerial components, indicating a phytostabilisation-controlling process. Root-based metals sequestration has been extensively reported in the literature as a protective mechanism in plants, which reduces the harm to photosynthetically active tissues and minimises the chances of introducing the metal into the food chain (Ghosh and Singh, 2005; Chehregani and Malayeri, 2007).

The limited translocation of arsenic between roots and shoots and leaves, as was found in this study, has been reported previously in Talinum triangulare, Zea mays and Colocasia esculenta, where heavy metals had been heavily held in root tissues (Gupta et al., 2009; Kumar et al., 2012; Bindu et al., 2010). The accumulation behaviour of this type of phytoremediation system enhances ecological safety by reducing the transfer of metals to edible or higher plant parts. Herbaceous ornamental plants such as *Portulaca grandiflora* and *Syngonium podophyllum* have shown strong cadmium tolerance and phytoextraction capacity, whereas *Tabernaemontana divaricata* was more effective in cadmium phytostabilisation, emphasising the potential of non-edible ornamental species for remediating Cd-contaminated sites (Mahajan et al., 2024). Barwal et al. (2025) reported that nano-bionics, through the integration of nanomaterials with plant systems, enhances stress tolerance, chemical sensing, light absorption, and overall plant productivity, offering new directions for sustainable agriculture.

Co-planting systems combining landscape trees with ornamental ground-cover species significantly increased heavy-metal accumulation and modified soil metal fractions in sewage sludge–amended soils, demonstrating that plant–plant interactions can enhance phytoremediation efficiency beyond monoculture approaches (Lai et al., 2022). In parallel, endophyte-assisted bioremediation has emerged as a sustainable strategy for treating heavy-metal-contaminated industrial effluents by promoting metal mobilisation, reducing phytotoxicity, and improving plant metal uptake through beneficial plant–microbe interactions, as highlighted by Harsonowati et al. (2024). Phytoremediation is widely recognised as a cost-effective green technology for the treatment of contaminated water and wastewater, relying on processes such as phytoextraction, phytofiltration, and phytodegradation, with efficiency strongly influenced by plant species, contaminant properties, and environmental conditions (Nazir, 2025). Liu et al. (2022) demonstrated in hydroponic studies that *Spathiphyllum kochii* exhibits high tolerance to multiple heavy metals, while sodium silicate supplementation effectively reduced metal uptake, enhanced antioxidant enzyme activity, and mitigated oxidative stress, thereby improving plant biomass. Recent developments in plant nanobionics, wearable plant sensors, and synthetic biology further indicate that living plants can be engineered as responsive, sustainable systems for environmental sensing, energy harvesting, and functional adaptation (Puangpathumanond et al., 2023).

The performance of *Syngonium podophyllum*, a terrestrial ornamental plant, compared with aquatic macrophytes commonly used in constructed wetlands indicates its flexibility in adapting to waterlogged conditions and its potential use in engineered wetlands. The ornamental use of plants offers additional advantages, including improved aesthetics, ease of care, and public acceptance, which are valuable factors in the large-scale application of phytoremediation technologies (Garbisu and Alkorta, 2003). Altogether, the research results of this project indicate that *Syngonium podophyllum* is a suitable option for arsenic phytoremediation in an arsenic-contaminated constructed wetland system, especially at low to moderate levels of contamination. The combination of a robust arsenic removal process, root-dominated concentration, and statistical confirmation underscores the potential of this plant species as a sustainable, low-cost, and environmentally friendly method for treating arsenic-contaminated wastewater.

Table 4. Key Phytoremediation and Bioremediation Studies

Sr. No.	Authors (Year)	System / Plant Type	Contaminant	Key Outcome (very brief)
1.	Fan et al. (2021)	Constructed wetlands (VFCW, HFCW)	Arsenic	40–53% (VFCW); >96% (HFCW)
2.	Lizama-Allende et al. (2021)	Subsurface wetland media	Arsenic	Media-driven removal
3.	Irshad et al. (2021)	Biochar–microbe wetland	Arsenic	~95% removal
4.	Roy et al. (2021)	Aquatic macrophytes	Arsenic	High uptake and tolerance
5.	Agrawal and Verma (2021)	Plant–microbe systems	Multi-pollutant	Sustainable remediation
6.	Lai et al. (2022)	Co-planting systems	Heavy metals	Enhanced accumulation
7.	Liu et al. (2022)	*Spathiphyllum* (hydroponic)	Heavy metals	Reduced stress uptake
8.	Teiri et al. (2022)	Indoor phytoremediation	$PM_{2.5}$, VOCs	Air quality improvement
9.	Zhou et al. (2023)	*Syngonium*–endophyte	Uranium	Root-dominated removal
10.	Chhimwal and Srivastava (2023)	*Syngonium*–fungal system	COD, BOD, Pb	Rapid treatment
11.	Puangpathumanond et al. (2023)	Plant nanobionics	Sensors / stress	Functional enhancement
12.	Rajalakshmi and Gunasekaran (2024)	Hydroponic NFT	Nitrate-N	70–90% removal
13.	Kankia et al. (2024)	Aquaponics	Nutrients	Improved recycling
14.	Harsonowati et al. (2024)	Endophyte-assisted systems	Heavy metals	Uptake enhancement
15.	Mahajan et al. (2024)	Ornamental plants	Cadmium	Phytoextraction/stabilization
16.	Rahman et al. (2025)	*Pennisetum* wetland	Arsenic	Complete removal (low As)
17.	Kaur et al. (2025)	Ornamental remediation	Multi-pollutant	Aesthetic sustainability
18.	Nazir (2025)	Review	Wastewater	Cost-effective green tech
19.	Barwal et al. (2025)	Plant nanobionics	Stress and sensing	Productivity gain

Conclusion

The current research demonstrated that *Syngonium podophyllum* has the potential to phytoremediate arsenic-contaminated wastewater in a constructed wetland (CW) system. The tremens efficiency was inversely related to the initial arsenic concentration, with the highest removal rate of 93.33% recorded at 5 mg L^{-1} after a 25-day exposure period. This concentration-dependent response indicates a threshold beyond which the plant metabolic uptake mechanism becomes inhibited. Analysis reveals a root-dominated accumulation pattern for the metal. The lower metal concentration is translocated to shoots and leaves. This below-ground biomass suggests that the primary mechanism at work is phytostabilisation, which minimises the risk of arsenic entry into the food chain and enhances the ecological safety of the remediation process. The demonstrated arsenic-removal capability makes *S. podophyllum* a sustainable, cost-effective option for treating wastewater contaminated with low to moderate levels of arsenic.

References

Agrawal K and Verma P (2021) Phytoremediation for the treatment of various types of pollutants: A multi-dimensional approach. In: Removal of refractory pollutants from wastewater treatment plants. 1st ed. CRC Press.

Ahmed YR, El-Hagrassi AM, Nasr NN, et al. (2024) Chemical composition and therapeutic potential of Syngonium podophyllum L. leaves against hypercholesterolemia in rats: Liver, kidney, and heart crosstalk. Current Bioactive Compounds 20(6):48–63. DOI: 10.2174/0115734072270545231107044558.

Ali H, Khan E and Sajad MA (2013) Phytoremediation of heavy metals—Concepts and applications. Chemosphere 91(7):869–881.

Arora M, Kiran B, Rani S, et al. (2008) Heavy metal accumulation in vegetables irrigated with water from different sources. Food Chemistry 111(4):811–815.

Barwal A, Chopra S, Kaur S, et al. (2025) Nano-bionics approach for augmentation of plant functions. In: Yadav SK and Kumari A (eds.) Nanobiotechnology in agri-food sector. Springer, Singapore, pp. 63–80. DOI: 10.1007/978-981-96-7756-6_4.

Bindu T, Sylas VP, Mahesh M, et al. (2010) Pollutant removal from domestic wastewater with Colocasia esculenta planted in a subsurface flow system. Ecological Engineering 33(1):68–82.

Bravo-Riquelme D and Lizama-Allende K (2024) Mathematical modeling of subsurface flow constructed wetlands performance for arsenic removal: Review and perspectives. Science of The Total Environment 949:175061. DOI: 10.1016/j.scitotenv.2024.175061.

Brix H, Arias CA and Del Bubba M (2007) Media selection for sustainable phosphorus removal in subsurface flow constructed wetlands. Water Science and Technology 56(3):47–54.

Chehregani A and Malayeri BE (2007) Removal of heavy metals by native accumulator plants. International Journal of Agriculture and Biology 9(3):462–465.

Chhimwal M and Srivastava RK (2023) Microcosmic plant and fungi synergism-based filter to remediate the pollutants from industrial wastewater. Materials Today: Proceedings 77(Part 1):322–327. DOI: 10.1016/j.matpr.2022.11.418.

Clemens S (2001) Molecular mechanisms of plant metal tolerance and homeostasis. Planta 212(4):475–486.

Fan Y, Li T, Cun D, et al. (2021) Removal of arsenic by pilot-scale vertical flow constructed wetland. Frontiers of Environmental Science and Engineering 15(4):79. DOI: 10.1007/s11783-021-1435-1.

Garbisu C and Alkorta I (2003) Basic concepts on heavy metal soil bioremediation. European Journal of Mineral Processing and Environmental Protection 3(1):58–66.

Genchi G, Lauria G, Catalano A, et al. (2022) Arsenic: A review on a great health issue worldwide. Applied Sciences 12(12):6184. DOI: 10.3390/app12126184.

Ghosh M and Singh SP (2005) A review on phytoremediation of heavy metals and utilisation of its byproducts. Applied Ecology and Environmental Research 3(1):1–18.

Gupta DK, Huang HG, Yang, et al. (2009) The detoxification of lead in Sedum alfredii Hance involves the production of thiol compounds. Plant Science 176(3):399–405.

Harsonowati W, Nurrahma AHI, Shah T, et al. (2024) Bioremediation of heavy metals contaminated industrial effluents by endophytes and their mechanisms. In: Bio-organic amendments for heavy metal remediation: Water, soil and plant approaches and technologies. Elsevier, pp. 57–67. DOI: 10.1016/B978-0-443-21610-7.00005-7.

Irshad S, Xie Z, Kamran M, et al. (2021) Biochar composite with microbes enhanced arsenic biosorption and phytoextraction by Typha latifolia in hybrid vertical subsurface flow constructed wetland. Environmental Pollution 291:118269. DOI: 10.1016/j.envpol.2021.118269.

Kankia AI, Manoj VR, Orugba HO, et al. (2024) Enhancing the sustainability of aquaculture systems via nutrient recycling using aquaponics system. Water, Air, and Soil Pollution 235:397. DOI: 10.1007/s11270-024-07214-1.

Kara Y (2005) Bioaccumulation of heavy metals in Oreochromis niloticus. Bulletin of Environmental Contamination and Toxicology 74(3):584–589.

Kaur J, Mudgal G and Dhar SK (2025) Decoration plants and their role in remediation. In: Abdel Latef AAH, Zayed EM and Omar AA (eds.) Sustainable remediation for pollution and climate resilience. Springer, Singapore, pp. 695–724. DOI: 10.1007/978-981-96-5674-5_25.

Kumar PBAN, Dushenkov V, Motto H, et al. (1995) Phytoextraction: The use of plants to remove heavy metals from soils. Environmental Science and Technology 29(5):1232–1238.

Lai M-L, Dong X-Q, Xie S-Y, et al. (2022) Plant adaptability and heavy metals accumulation of different landscape plants in soil applied with sewage sludge. Journal of South China Agricultural University 43(4):47–57. DOI: 10.7671/j.issn.1001-411X.202108021.

Liu K, Dai C, Li C, et al. (2022) Plant growth and heavy metal accumulation characteristics of Spathiphyllum kochii cultured in three soil extractions with and without silicate supplementation. International Journal of Phytoremediation 25(4):524–537. DOI: 10.1080/15226514.2022.2092059.

Lizama-Allende K, Ayala J, Jaque I, et al. (2021) The removal of arsenic and metals from highly acidic water in horizontal subsurface flow constructed wetlands with alternative supporting media. Journal of Hazardous Materials 408:124832. DOI: 10.1016/j.jhazmat.2020.124832.

Mahajan P, Kaushal J and Pandey VC (2024) Assessment of herbaceous ornamental plant species as potential remediation agents for cadmium contaminated environments. Journal of Geochemical Exploration 256:107333. DOI: 10.1016/j.gexplo.2023.107333.

Martínez-Castillo M, García-Montalvo EA, Arellano-Mendoza MG, et al. (2021) Arsenic exposure and non-carcinogenic health effects. Human and Experimental Toxicology 40(12_suppl):S826–S850. DOI: 10.1177/09603271211045955.

Mudipalli A (2008) Lead hepatotoxicity and potential health effects. Indian Journal of Medical Research 128(4):463–474.

Nazir R (2025) Phytoremediation: A single approach for treatment of heavy metals and agrochemicals from contaminated water. In: Yatoo AM and Sillanpää M (eds.) Smart waste and wastewater management by biotechnological approaches. Springer, Singapore, pp. 241–262. DOI: 10.1007/978-981-97-8673-2_12.

Park JK and Oh K (2023) Advancements in phytoremediation research for soil and water resources: Harnessing plant power for environmental cleanup. Sustainability 15(18):13901. DOI: 10.3390/su151813901.

Prasad MNV (2003) Phytoremediation of metal-polluted ecosystems. Plant Science 164(6):935–945.

Puangpathumanond S, Qiu Q and Lew TTS (2023) Engineering plants as sustainable living devices. MRS Bulletin 48:1086–1095. DOI: 10.1557/s43577-023-00505-8.

Rahman ME, Mahmud K, Uddin MK, et al. (2025) Phytotoxicity and uptake of arsenic through Pennisetum purpureum in a pilot-scale constructed wetland arrangement. Environmental Technology. DOI: 10.1080/10889868.2025.2482660.

Rahman MM and Hasegawa H (2011) Aquatic arsenic: Phytoremediation using floating macrophytes. Chemosphere 83(5):633–646.

Rosendo JCM, da Paz GM and Rosendo A (2022) Constructed wetlands applied on domestic wastewater for decentralized systems: Concepts, processes, modalities, combinations and enhancements; a review. Reviews in Environmental Science and Bio/Technology 21(2):371–397. DOI: 10.1007/s11157-022-09616-1.

Roy D, Sreekanth D, Pawar D, et al. (2021) Phytoremediation of arsenic contaminated water using aquatic, semi-aquatic and submerged weeds. In: Mendes KF, de Sousa RN and Mielke KC (eds.) Biodegradation technology of organic and inorganic pollutants. IntechOpen. DOI: 10.5772/intechopen.98961.

Salt DE, Smith RD and Raskin I (1998) Phytoremediation. Annual Review of Plant Physiology and Plant Molecular Biology 49(1):643–668.

Song S, Sheng Q, Zhu Z, et al. (2023) Application of multi-plant symbiotic systems in phytoremediation: A bibliometric review. Sustainability 15(16):12252. DOI: 10.3390/su151612252.

Suresh B and Ravishankar GA (2004) Phytoremediation—A novel and promising approach for environmental clean-up. Critical Reviews in Biotechnology 24(2–3):97–124.

Tangahu BV, Sheikh Abdullah SR, Basri H, et al. (2011) A review on heavy metals (As, Pb, and Hg) uptake by plants through phytoremediation. International Journal of Chemical Engineering 2011:1–31.

Teiri H, Hajizadeh Y and Azhdarpoor A (2022) A review of different phytoremediation methods and critical factors for purification of common indoor air pollutants: An approach with sensitive analysis. Air Quality, Atmosphere and Health 15:373–391. DOI: 10.1007/s11869-021-01124-6.

Uddin S, Afroz H, Hossain M, et al. (2023) Heavy metals/metalloids in food crops and their implications for human health. In: Heavy metal toxicity and tolerance in plants: A biological, omics, and genetic engineering approach. pp. 59–86. DOI: 10.1002/9781119906506.ch3.

Ullah S, Liu Q, Wang S, et al. (2023) Sources, impacts, factors affecting Cr uptake in plants, and mechanisms behind phytoremediation of Cr-contaminated soils. Science of the Total Environment 899:165726. DOI: 10.1016/j.scitotenv.2023.165726.

Van Aken B (2009) Transgenic plants for phytoremediation: Helping nature to clean up environmental pollution. Trends in Biotechnology 27(10):496–503.

Vijayan DS, Koda E, Sivasuriyan A, et al. (2023) Advancements in solar panel technology in civil engineering for revolutionizing renewable energy solutions—A review. Energies 16(18):6579. DOI: 10.3390/en16186579.

Vymazal J (2009) The use of constructed wetlands with horizontal subsurface flow for various types of wastewater. Ecological Engineering 35(1):1–17.

Wang J, Wang W, Xiong J, et al. (2021) A constructed wetland system with aquatic macrophytes for cleaning contaminated runoff/storm water from urban area in Florida. Journal of Environmental Management 280:111794. DOI: 10.1016/j.jenvman.2020.111794.

Wuana RA and Okieimen FE (2011) Heavy metals in contaminated soils: A review of sources, chemistry, risks and best available strategies for remediation. ISRN Ecology 2011:1–20.

Yoon J, Cao X, Zhou Q, et al. (2006) Accumulation of Pb, Cu, and Zn in native plants growing on a contaminated Florida site. Science of the Total Environment 368(2–3):456–464.

Madjar RM and Vasile Scaețeanu G (2025) An overview of heavy metal contamination in water from agriculture: Origins, monitoring, risks, and control measures. Sustainability 17(16):7368. DOI: 10.3390/su17167368.

Yue Z, Dexin D, Guangyue L, et al. (2021) Enhanced effects and mechanisms of Syngonium podophyllum-Peperomia tetraphylla co-planting on phytoremediation of low concentration uranium-bearing wastewater. Chemosphere 279:130810. DOI: 10.1016/j.chemosphere.2021.130810.

Zaman W, Ali S and Akhtar MS (2024) Harnessing the power of plants: Innovative approaches to pollution prevention and mitigation. Sustainability 16(23):10587. DOI: 10.3390/su162310587.

Zhou TH, He L, Deng QW, et al. (2023) Experimental study of remediation of wastewater with low concentrations of uranium using Syngonium podophyllum–endophyte symbiotic systems. International Journal of Environmental Science and Technology 20:1769–1778. DOI: 10.1007/s13762-022-04069-z.

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