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Accumulation Of Zn, Cu, Fe And Mn In Typha Latifolia Growing In A Pilot Constructed Wetland Treating Mining Drainage Water (Bolnisi, Georgia)

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Abstract

Background and Objective - Constructed wetlands are increasingly used as nature-based polishing systems to remove residual contaminants from industrial effluents following conventional treatment processes. This study evaluated the accumulation of residual heavy metals by *Typha latifolia* in a pilot constructed wetland receiving treated mining drainage water from a tailings facility in Bolnisi, Georgia.

Methods - Field monitoring was conducted monthly between May and September 2025. Water, sediment, and plant samples were collected to assess the distribution of zinc (Zn), copper (Cu), iron (Fe), and manganese (Mn) within the wetland system. Plant tissues were digested following the EPA 3050B protocol, and metal concentrations were determined by atomic absorption spectrometry in accordance with ISO 8288-A:1986. Water samples were analyzed using a Hach DR-3900 spectrophotometer.

Results - Metal accumulation was strongly concentrated in root tissues, whereas substantially lower concentrations were detected in leaves and flowers. Iron and manganese exhibited the highest concentrations in plant biomass, with clear evidence of root-dominated retention. Translocation factor values below unity for all investigated metals indicated limited movement from roots to above-ground tissues, supporting phytostabilization as the dominant remediation mechanism. Additional upstream–downstream monitoring conducted in 2026 demonstrated an average manganese removal efficiency of 67%, suggesting that the wetland contributes to the attenuation of residual metals.

Conclusion - The findings indicate that *Typha latifolia* acts mainly as a phytostabilizing species in the investigated wetland and suggest that constructed wetlands may serve as a low-cost supplementary treatment stage for chemically treated mining wastewater. Long-term studies are needed to confirm these preliminary results.

Keywords - phytostabilization; wetland macrophytes; metal translocation; nature-based treatment; manganese removal; rhizosphere retention.

I. INTRODUCTION

Mining and ore processing activities represent one of the major anthropogenic sources of heavy metal contamination in aquatic environments [1]. Wastewater generated during mineral processing and tailings management often contains elevated concentrations of metals such as iron, manganese, copper and zinc [2], [3]. Although chemical treatment technologies can significantly reduce metal concentrations, residual amounts of contaminants may still remain in treated effluents.

In Georgia, the Bolnisi mining district of the Kvemo Kartli region, where the RMG (formerly Madneuli) gold–copper deposit at Kazreti has been exploited by open-pit mining since the 1970s, is regarded as one of the most mining-impacted areas of the country [4], [5]. Concentrations of Cu, Zn and Cd exceeding permissible limits have been reported in agricultural soils of villages located near the mine [6], [7], and an increase in soil heavy metal levels between 2014 and 2017 has been documented [5]. Elevated concentrations of toxic elements have also been detected in the Mashavera River basin [8], while past irrigation with contaminated water has been linked to metal accumulation in agricultural soils of the region [9].

Constructed wetlands have become an increasingly popular nature-based solution for the final polishing of treated wastewater [10], [3]. These systems utilize the combined action of physical, chemical and biological processes to remove pollutants [11], [12]. Among the biological components, aquatic macrophytes play a key role in contaminant removal through mechanisms such as adsorption, precipitation, rhizosphere interactions and plant uptake [13], [14].

Typha latifolia L., commonly known as cattail, is one of the most widely distributed wetland macrophytes and has been extensively studied for its phytoremediation potential [15], [16], [17]. The species demonstrates high tolerance to polluted environments and produces significant biomass, making it suitable for applications in wetland treatment systems [18].

Despite the growing global interest in phytoremediation, limited studies have investigated the role of wetland vegetation in mining wastewater treatment systems in the Caucasus region. Previous research in the Bolnisi district has focused mainly on the contamination of soils, surface waters and crops [6], [5], [8] and on the phytoremediation of contaminated agricultural soils [19], whereas the performance of wetland vegetation in treating mining drainage water has received little attention. Therefore, the present study aims to evaluate the capacity of *Typha latifolia* to accumulate residual heavy metals from treated mining wastewater in a pilot constructed wetland located near the RMG tailings facility in Bolnisi, Georgia.

It was hypothesized that *Typha latifolia* preferentially accumulates metals in its roots rather than in aerial organs, indicating limited translocation of heavy metals within the plant.

This study provides site-specific evidence of heavy metal accumulation by Typha latifolia in a pilot constructed wetland treating mining drainage water in the Bolnisi mining region of Georgia.

II. STUDY AREA

The study was conducted in a pilot constructed wetland located near the RMG mining tailings facility in the Bolnisi region of southern Georgia. The RMG (formerly Madneuli) gold–copper deposit is located at Kazreti, on the banks of the Mashavera and Kazretula rivers, approximately 80 km southwest of Tbilisi [7].

The geographic coordinates of the study site are:

UTM Zone: 38T

Easting: 452,927 m

Northing: 4,583,036 m

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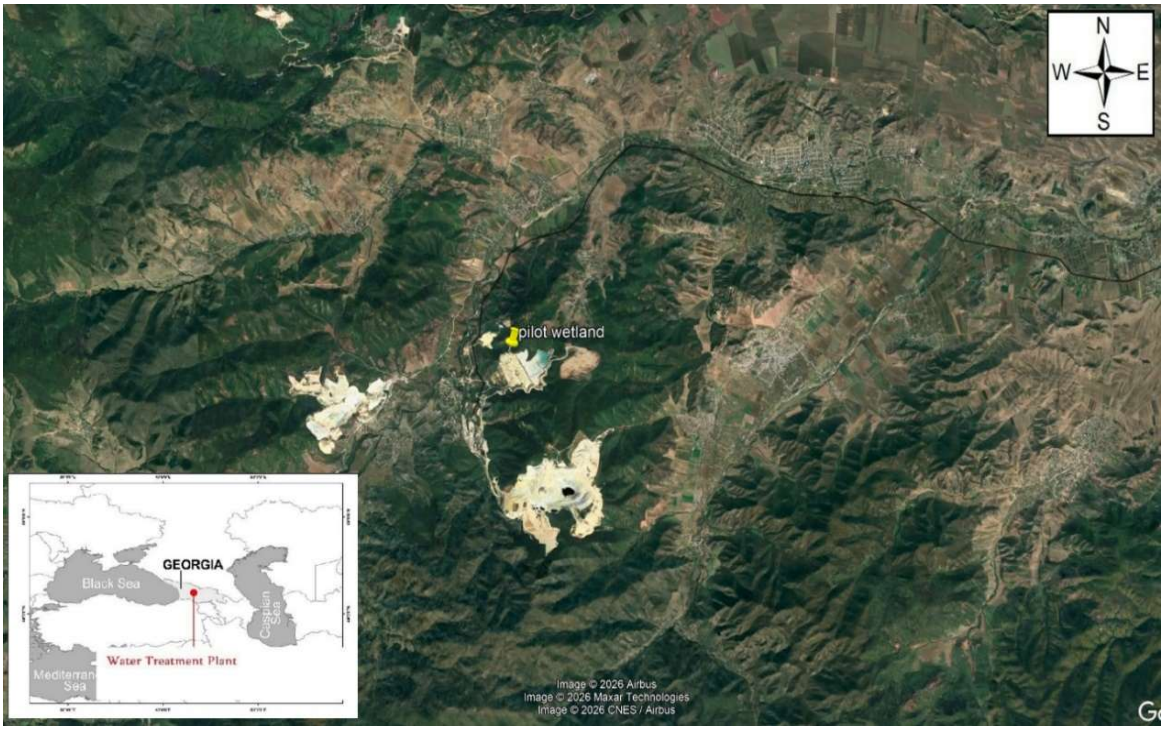

Figure 1. Location of the pilot constructed wetland used for the phytoremediation study in the Bolnisi mining region, Georgia. The wetland receives drainage water from the RMG tailings facility and functions as a natural polishing stage following chemical wastewater treatment.

The wetland is an artificially formed treatment system with an approximate surface area of about **65 m²**. The system receives drainage water originating from the tailings facility and serves as a natural polishing stage following chemical treatment processes.

Water in the wetland flows slowly with a depth ranging from **0.30 to 0.60 m**. The wetland substrate consists mainly of **silty-sandy sediment**, providing suitable conditions for the growth of wetland vegetation.

The vegetation of the wetland is dominated by Typha latifolia, which forms dense stands across the system. Preliminary observations indicated that manganese concentrations in the wetland water were relatively higher compared to other metals, while pH values remained within neutral ranges.

III. MATERIALS AND METHODS

3.1. Sampling design

Field sampling was conducted on a monthly basis from May to September 2025 in the pilot constructed wetland located near the RMG mining tailings facility in Bolnisi, Georgia. During each sampling campaign, plant and water samples were collected simultaneously from the wetland system, while a sediment sample was additionally collected during one of the campaigns.

A total of five sampling campaigns were carried out during the monitoring period. In each campaign, samples of *Typha latifolia* were collected in order to investigate metal accumulation dynamics during plant growth.

All plant samples were collected from mature and healthy individuals growing within the wetland vegetation zone.

At the beginning of the monitoring period in May, the average plant height was approximately **0.90 m**, whereas during the later sampling campaigns the plant height ranged between **1.20 m and 1.60 m**.

Plant samples were separated into individual organs including **roots, leaves, and flowers** prior to laboratory analysis in order to evaluate organ-specific metal accumulation.

Water samples were collected simultaneously with plant sampling events, resulting in **five water samples** collected during the study period. In addition, a sediment sample was collected from the bottom layer of the wetland to determine heavy metal concentrations in the substrate.

3.2. Water analysis

Water samples were analyzed in the environmental laboratory of **RMG Gold LLC**. Prior to analysis, collected water samples were filtered using laboratory filter paper in order to remove suspended particles.

The **pH of filtered water samples** was measured using a calibrated pH meter. After filtration, samples were diluted with distilled water using volumetric pipettes to obtain suitable concentrations for spectrophotometric analysis.

Metal concentrations were determined using a **Hach DR-3900 spectrophotometer**. Specific Hach reagent kits were used for the determination of individual metals. Powder reagent pillows were applied for Cu and Fe determination, while the Zinc reagent powder pillow method was used for Zn determination. Mn was determined using the periodate oxidation method with Hach powder pillows.

After reagent addition, samples were thoroughly mixed and transferred into glass cuvettes before being inserted into the spectrophotometer. Blank solutions were prepared simultaneously in order to ensure proper calibration of the analytical procedure.

Table 1 — Physicochemical characteristics of wetland water.

N	Sampling area	Wetland	Sampling date	pH	Zn (mg/L)	Cu (mg/L)	Fe (mg/L)	Mn (mg/L)
1	Pilot Wetland	Water	30-05-2025	7.65	0.84	0.66	0.14	3.86
2	Pilot Wetland	Water	30-06-2025	7.72	0.34	0.07	0.05	2.47
3	Pilot Wetland	Water	24-07-2025	7.28	0.78	0.42	0.06	2.16
4	Pilot Wetland	Water	30-08-2025	7.40	0.40	0.08	0.06	1.73
5	Pilot Wetland	Water	24-09-2025	7.62	0.18	1.60	0.12	0.53

3.3. Sediment analysis

A sediment sample was collected from the bottom layer of the wetland and transported to the laboratory for analysis. The sample was analyzed using atomic absorption spectrometry (AAS) according to UNEP Reference Method No. 63 [20]. Prior to analysis, the sediment sample was air-dried and homogenized. The dried sample was sieved to obtain a uniform particle size prior to metal analysis.

This method allows the determination of trace metal concentrations in sediment samples following appropriate digestion procedures.

Table 2 — Heavy metal concentrations in wetland sediment.

N	Sampling area	Wetland	Sampling date	Zn (mg/kg)	Cu (mg/kg)	Fe (mg/kg)	Mn (mg/kg)
1	Pilot Wetland	Sediment	31-07-2025	97	100	21000	1631

3.4. Plant sample preparation and analysis

Plant samples of Typha latifolia were washed with distilled water to remove adhered particles and then separated into roots, leaves, and flowers. The plant material was dried at room temperature and subsequently ground into a fine powder prior to acid digestion.

The samples were subjected to acid digestion using the EPA 3050B protocol [21], which was originally developed for solid matrices such as soils and sediments and was applied here to dried and homogenized plant material. Sample preparation followed the Plant Processing for Trace Metal Analysis Protocol [22].

After digestion, the resulting solutions were analyzed using atomic absorption spectrometry (AAS) according to ISO 8288-A:1986 [23] for the determination of Zn, Cu, Mn and Fe concentrations.

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Table 3 — Heavy metal concentrations (mg/kg) in different organs of **Typha latifolia.**

N	Sample number	Sampling area	Plant	Sampling time	Plant organs	Zn (mg/kg)	Cu (mg/kg)	Fe (mg/kg)	Mn (mg/kg)
1	10.01	Pilot Wetland	Typha latifolia	30-05-2025	Root	40	54	4000	1000
2	10.02	Pilot Wetland	Typha latifolia	30-05-2025	Leaf	<20	<20	40	700
3	11.01	Pilot Wetland	Typha latifolia	30-06-2025	Root	40	48	4800	2700
4	11.02	Pilot Wetland	Typha latifolia	30-06-2025	Leaf	30	<20	60	700
5	11.03	Pilot Wetland	Typha latifolia	30-06-2025	Flower	<20	<20	<40	700
6	12.01	Pilot Wetland	Typha latifolia	24-07-2025	Root	<20	114	4500	560
7	12.02	Pilot Wetland	Typha latifolia	24-07-2025	Leaf	<20	<20	<40	400
8	12.03	Pilot Wetland	Typha latifolia	24-07-2025	Flower	20	<20	40	630
9	13.01	Pilot Wetland	Typha latifolia	30-08-2025	Root	40	20	1700	240
10	13.02	Pilot Wetland	Typha latifolia	30-08-2025	Leaf	20	<20	40	450
11	13.03	Pilot Wetland	Typha latifolia	30-08-2025	Flower	20	<20	<40	370
12	14.01	Pilot Wetland	Typha latifolia	24-09-2025	Root	20	<20	1600	620
13	14.02	Pilot Wetland	Typha latifolia	24-09-2025	Leaf	<20	<20	<40	900
14	14.03	Pilot Wetland	Typha latifolia	24-09-2025	Flower	<20	<20	<40	400

3.5. Statistical analysis

The translocation factor (TF) was calculated to evaluate the transfer of metals from roots to aerial plant organs [17].

TF = Cshoot / Croot

where Cshoot represents the concentration of metals in leaves and flowers (mg kg^{-1}) and Croot represents the concentration in root tissues (mg kg^{-1}).

Metal concentration data obtained during the study were processed using descriptive statistical methods. Average values were calculated in order to evaluate the distribution of metals in different plant organs and environmental matrices. Concentrations below the detection limit were assigned a value equal to half of the detection limit for the calculation of average values. Data processing and statistical calculations were performed using Microsoft Excel, while graphical visualization was carried out using Python (Matplotlib).

Comparisons between root and aerial plant organs were used to assess metal accumulation patterns and possible translocation within the plant tissues.

IV. RESULTS

Water analysis revealed the presence of several residual heavy metals in the pilot wetland system. Among the analyzed elements, manganese exhibited the highest concentrations in water samples, while zinc and copper were present at lower levels.

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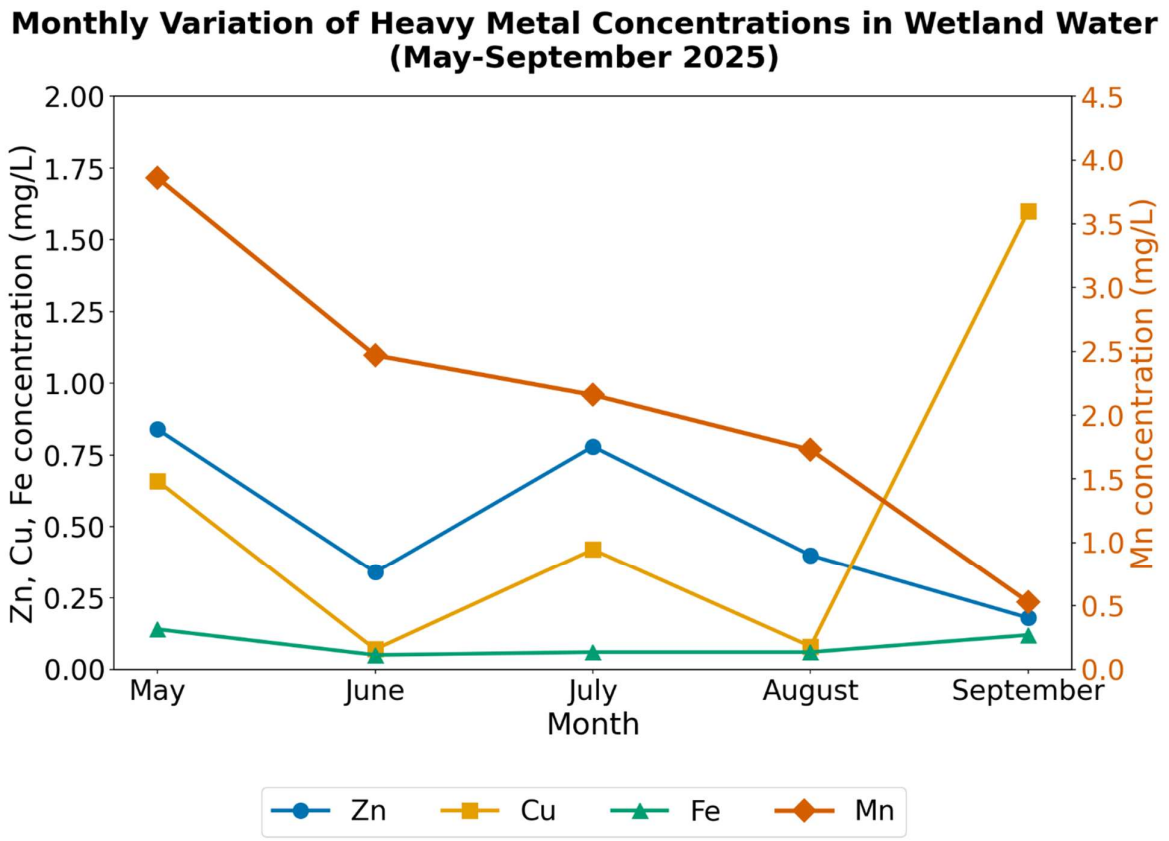

Figure 2. Monthly variation of heavy metal concentrations (Zn, Cu, Fe and Mn) in water samples collected from the pilot constructed wetland between May and September 2025.

Manganese concentrations showed a generally decreasing trend throughout the monitoring period, declining from 3.86 mg/L in May to 0.53 mg/L in September. Copper concentrations remained relatively low during most sampling campaigns; however, a localized increase was observed in September, when the concentration reached 1.60 mg/L.

The analysis of plant tissues revealed that heavy metals were primarily accumulated in the **root system of Typha latifolia**. This root-dominated accumulation pattern was observed for all investigated metals including Fe, Mn, Zn and Cu.

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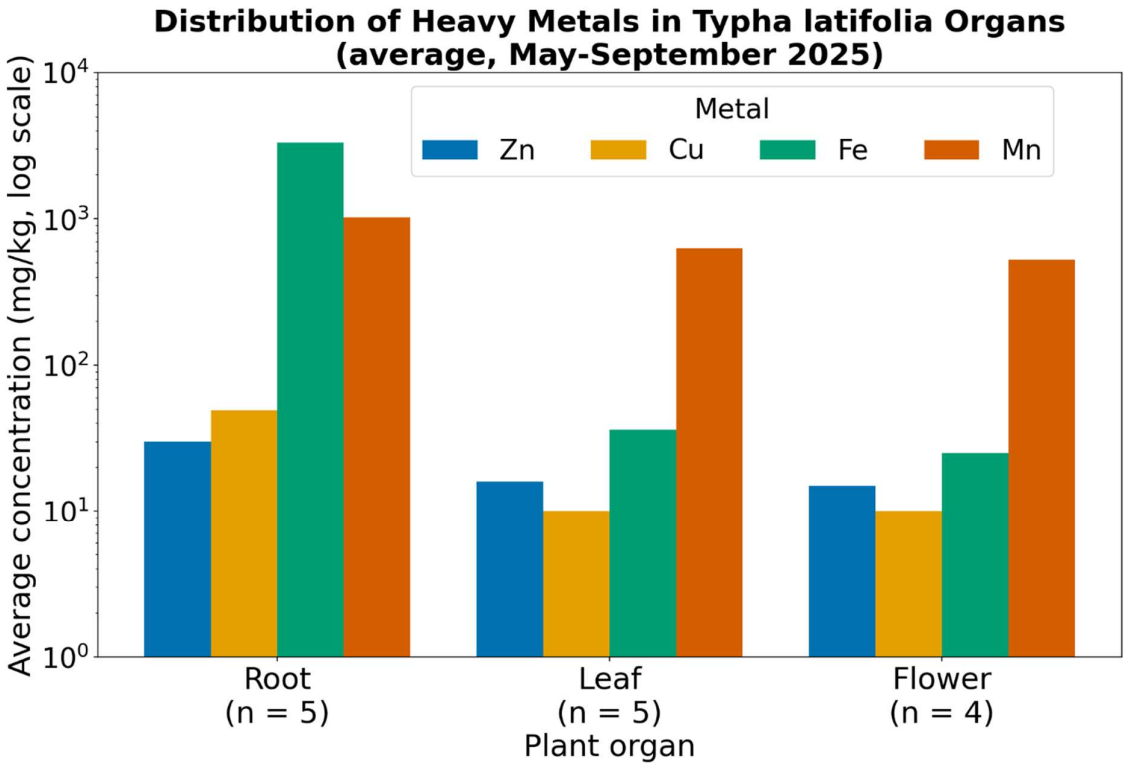

Figure 3. Distribution of heavy metals in Typha latifolia organs. Values represent average concentrations (mg/kg dry weight) of samples collected monthly from May to September 2025 (roots and leaves, n = 5; flowers, n = 4).

Among the investigated metals, **iron (Fe)** showed the highest concentration in plant tissues, particularly in the roots. Manganese (Mn) also exhibited elevated concentrations, which is consistent with the relatively higher manganese concentrations detected in the wetland water.

In contrast, metal concentrations in the **above-ground plant organs (leaves and flowers)** were substantially lower compared to root tissues.

This pattern indicates that metal uptake occurs primarily through the root system, while internal transport of metals to aerial tissues remains limited. This behavior is typical for many emergent wetland macrophytes growing in contaminated aquatic environments [13], [17].

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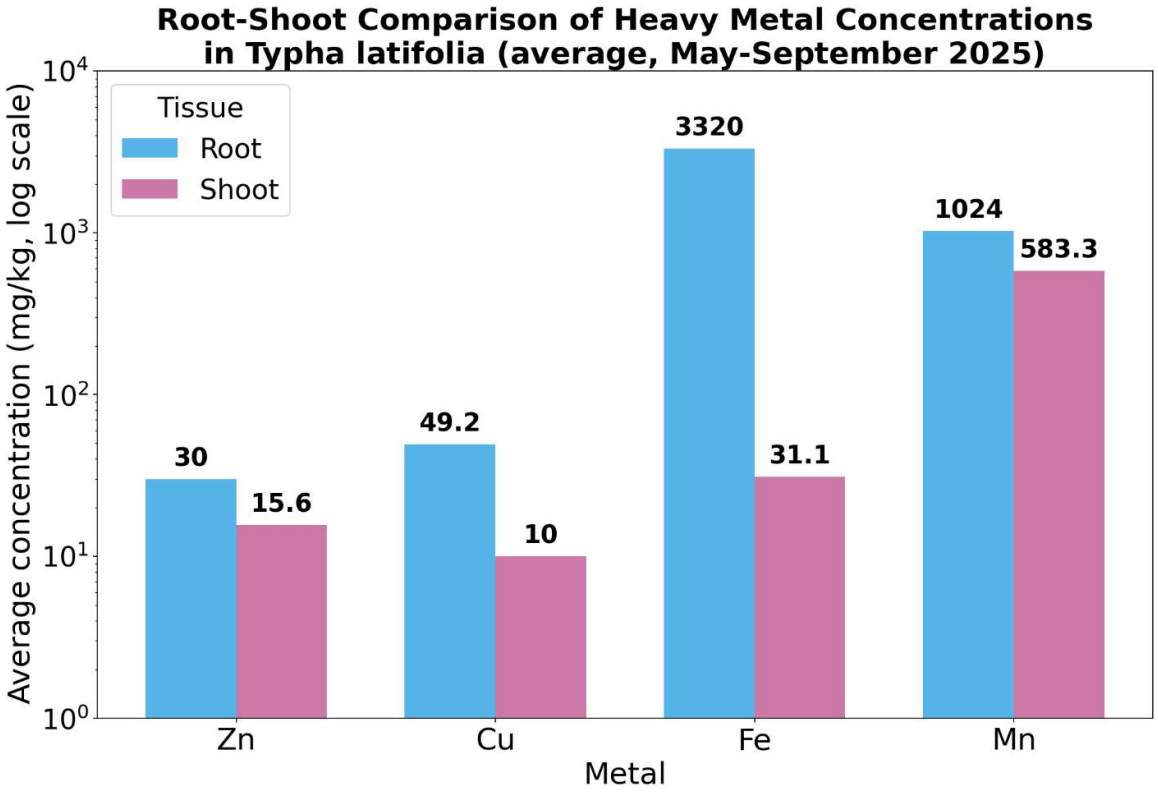

Figure 4. Root–shoot comparison of heavy metal concentrations in Typha latifolia. Values represent average concentrations (mg/kg) of samples collected from May to September 2025 (roots n = 5; shoots, including leaves and flowers, n = 9).

Table 4. Translocation factor (TF) of heavy metals in *Typha latifolia* based on average root and shoot concentrations.

Metal	Root average (mg/kg)	Shoot average (mg/kg)	TF
Zn	30	15.6	0.52
Cu	49.2	10	0.20
Fe	3320	31.1	0.01
Mn	1024	583.3	0.57

The calculated translocation factor (TF) values for all investigated metals were below 1, indicating limited transfer from roots to aerial tissues and supporting the interpretation of *Typha latifolia* as a predominantly phytostabilizing species in the investigated wetland system [24], [25].

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Table 5. Manganese removal efficiency in the pilot wetland system (2026)

Date	Upstream Mn (mg/L)	Downstream Mn (mg/L)	Removal (%)
23 Apr 2026	3.90	1.13	71.0
30 Apr 2026	2.96	0.82	72.3
11 May 2026	2.47	1.04	57.9
22 May 2026	2.16	0.43	80.1
03 Jun 2026	3.73	1.28	65.7
11 Jun 2026	3.39	1.52	55.2
Average	3.10	1.04	67.0

The monitoring results showed a consistent reduction of manganese concentrations between the upstream and downstream sampling points of the wetland. The average manganese concentration decreased from 3.10 mg/L upstream to 1.04 mg/L downstream of the wetland, corresponding to an average removal efficiency of 67.0%. These data extend the 2025 pilot campaign through follow-up monitoring conducted at the same wetland in 2026.

V. DISCUSSION

Root-dominated accumulation of all four investigated metals, with Fe and Mn showing the highest concentrations in roots, indicates that *Typha latifolia* contributed to the retention of residual metals in the investigated wetland. The high Fe content measured in the wetland sediment (21,000 mg/kg) suggests that the sediment is also an important metal reservoir in the system, which is consistent with the sulfide-rich, barite–gold–copper–polymetallic ore geology of the Kazreti deposit [5]. However, because only one sediment sample was analyzed, this observation should be verified by additional sampling.

Translocation factor values below 1 for all investigated metals indicate limited transfer from roots to leaves and flowers. According to commonly used criteria, such a pattern corresponds to phytostabilization rather than phytoextraction [25]. Similar retention of metals predominantly in root tissues has been reported for Typha species and other wetland plants growing in metal-contaminated environments [13], [17]. It should be noted that the roots were rinsed only with distilled water; therefore, part of the Fe and Mn measured in root tissues may be associated with metal plaques on the root surface [26].

Manganese showed the highest concentrations in wetland water and was therefore used as the main indicator of treatment performance. During six sampling events in 2026, the average Mn concentration decreased from 3.10 mg/L upstream to 1.04 mg/L downstream of the wetland. Possible mechanisms of this reduction include sorption to sediment, oxidation and precipitation in the root zone, microbial activity and plant uptake [10], [14]; however, the relative contribution of these processes was not quantified in this study and requires further investigation.

These preliminary results suggest that the pilot wetland may serve as a supplementary polishing stage after the chemical treatment of mining drainage water, as has been reported for other constructed wetlands receiving mining and industrial effluents [2], [3]. However, plant sampling covered a single growing season and Mn removal was assessed on the basis of six upstream–downstream measurements; long-term, seasonal and more detailed studies are therefore needed to confirm the treatment performance and the long-term stability of the retained metals. Given the documented metal contamination of soils and surface waters in the Bolnisi district [8], [5], such studies would be of particular regional relevance.

VI. CONCLUSION

This study examined the accumulation of residual heavy metals by Typha latifolia in a pilot constructed wetland receiving chemically treated mining drainage water from a tailings facility in Bolnisi, Georgia. Metal accumulation was concentrated in root tissues, with Fe and Mn showing the highest concentrations, while substantially lower levels were detected in leaves and flowers. Together with translocation factor values below unity, these results indicate that phytostabilization is the main mechanism of metal retention by T. latifolia in the investigated wetland.

Upstream–downstream monitoring during six sampling events in 2026 showed an average manganese removal efficiency of 67%, suggesting that the wetland can contribute to the reduction of residual metal concentrations after conventional chemical treatment.

Long-term monitoring covering seasonal variability, the analysis of additional sediment samples and wetland plant species, and a quantitative assessment of the individual removal mechanisms are needed to confirm these preliminary findings.

REFERENCES

[1] Rai, P.K. (2008). Heavy metal pollution in aquatic ecosystems and its phytoremediation using wetland plants: An ecosustainable approach. International Journal of Phytoremediation, 10(2), 133–160.

[2] Mays, P.A., & Edwards, G.S. (2001). Comparison of heavy metal accumulation in a natural wetland and constructed wetlands receiving acid mine drainage. Ecological Engineering, 16(4), 487–500.

[3] Wu, S., Wallace, S., Brix, H., Kuschk, P., Kirui, W.K., Masi, F., & Dong, R. (2015). Treatment of industrial effluents in constructed wetlands: Challenges, operational strategies and overall performance. Environmental Pollution, 201, 107–120.

[4] Kalandadze, B., & Matchavariani, L. (2019). Soil pollution. In L. Matchavariani (Ed.), The Soils of Georgia (pp. 153–166). Springer, Cham. https://doi.org/10.1007/978-3-030-18509-1_8

[5] Avkopashvili, M., Avkopashvili, G., Avkopashvili, I., Asanidze, L., Matchavariani, L., Gongadze, A., & Gakhokidze, R. (2022). Mining-related metal pollution and ecological risk factors in South-Eastern Georgia. Sustainability, 14(9), 5621. https://doi.org/10.3390/su14095621

[6] Avkopashvili, G., Avkopashvili, M., Gongadze, A., Tsulukidze, M., & Shengelia, E. (2017). Determination of Cu, Zn and Cd in soil, water and food products in the vicinity of RMG gold and copper mine, Kazreti, Georgia. Annals of Agrarian Science, 15(2), 269–272. https://doi.org/10.1016/j.aasci.2017.05.001

[7] Avkopashvili, M., Gongadze, A., Avkopashvili, G., Matchavariani, L., Asanidze, L., & Lagidze, L. (2020). Metals distribution in soil contaminated by gold and copper mining in Georgia. Journal of Environmental Biology, 41(2), 310–317. https://doi.org/10.22438/jeb/41/2(SI)/JEB-05

[8] Withanachchi, S.S., Ghambashidze, G., Kunchulia, I., Urushadze, T., & Ploeger, A. (2018). Water quality in surface water: A preliminary assessment of heavy metal contamination of the Mashavera River, Georgia. International Journal of Environmental Research and Public Health, 15(4), 621. https://doi.org/10.3390/ijerph15040621

[9] Gventsadze, G., Ghambashidze, G., Chankseliani, Z., Sarjveladze, I., & Blum, W.E.H. (2024). Impacts of crop-specific agricultural practices on the accumulation of heavy metals in soil in Kvemo Kartli region (Georgia): A preliminary assessment. Sustainability, 16(10), 4244. https://doi.org/10.3390/su16104244

[10] Kadlec, R.H., & Wallace, S. (2009). Treatment Wetlands (2nd ed.). CRC Press.

[11] Vymazal, J. (2010). Constructed wetlands for wastewater treatment. Water, 2(3), 530–549.

[12] Mitsch, W.J., & Gosselink, J.G. (2015). Wetlands (5th ed.). Wiley.

[13] Weis, J.S., & Weis, P. (2004). Metal uptake, transport and release by wetland plants: Implications for phytoremediation and restoration. Environment International, 30(5), 685–700.

[14] Marchand, L., Mench, M., Jacob, D.L., & Otte, M.L. (2010). Metal and metalloid removal in constructed wetlands, with emphasis on the importance of plants and standardized measurements: A review. Environmental Pollution, 158(12), 3447–3461.

[15] Ye, Z.H., Baker, A.J.M., Wong, M.H., & Willis, A.J. (1997). Zinc, lead and cadmium tolerance, uptake and accumulation by Typha latifolia. New Phytologist, 136(3), 469–480.

[16] Vymazal, J. (2013). Emergent plants used in free water surface constructed wetlands: A review. Ecological Engineering, 61, 582–592.

[17] Bonanno, G., & Cirelli, G.L. (2017). Comparative analysis of element concentrations and translocation in three wetland congener plants: Typha domingensis, Typha latifolia and Typha angustifolia. Ecotoxicology and Environmental Safety, 143, 92–101. https://doi.org/10.1016/j.ecoenv.2017.05.021

[18] Brisson, J., & Chazarenc, F. (2009). Maximizing pollutant removal in constructed wetlands: Should we pay more attention to macrophyte species selection? Science of the Total Environment, 407(13), 3923–3930. https://doi.org/10.1016/j.scitotenv.2008.05.047

[19] Avkopashvili, G., Gongadze, A., Gakhokidze, R., & Avkopashvili, M. (2015). Phytoremediation of contaminated soils, contaminated with heavy metals from gold mine in Georgia. In Proceedings of the International Conference “Applied Ecology: Problems, Innovations” (pp. 154–157). Tbilisi, Georgia.

[20] UNEP/IOC/IAEA. (1995). Manual for the geochemical analyses of marine sediments and suspended particulate matter. Reference Methods for Marine Pollution Studies No. 63. United Nations Environment Programme.

[21] US EPA. (1996). Method 3050B: Acid digestion of sediments, sludges, and soils (Revision 2). United States Environmental Protection Agency, Washington, DC.

[22] Richardson, J. (2018). Plant processing for trace metal analysis protocol. protocols.io.

[23] ISO. (1986). ISO 8288:1986 Water quality — Determination of cobalt, nickel, copper, zinc, cadmium and lead — Flame atomic absorption spectrometric methods. International Organization for Standardization, Geneva.

[24] Salt, D.E., Smith, R.D., & Raskin, I. (1998). Phytoremediation. Annual Review of Plant Physiology and Plant Molecular Biology, 49, 643–668.

[25] Ali, H., Khan, E., & Sajad, M.A. (2013). Phytoremediation of heavy metals—Concepts and applications. Chemosphere, 91(7), 869–881.

[26] Batty, L.C., Baker, A.J.M., Wheeler, B.D., & Curtis, C.D. (2000). The effect of pH and plaque on the uptake of Cu and Mn in Phragmites australis (Cav.) Trin ex. Steudel. Annals of Botany, 86(3), 647–653.