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ORIGINAL RESEARCH PAPER

STUDIES AND RESEARCHES ON *TYPHA LATIFOLIA*'S (BULRUSH) ABSORPTION CAPACITY OF HEAVY METALS FROM THE SOIL

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Abstract: The research aimed to determine *Typha latifolia*'s (bulrush) absorption capacity of heavy metals from the soil in the industrial area of Piatra Neamt city, Romania. Heavy metals present in ecological systems are available to the absorption process only partially, depending on the type of *p*H of the environment, their chemical composition, and the quantity of heavy metals in the soil, plants, sediments, water, or air. The choice of sampling points (the industrial area of Piatra Neamt city) took into consideration the areas where the pollution sources are located and where the sediment layer is thick and the granularity level is lower than 63 µm. The investigation of *Typha latifolia*'s absorption capacity showed that, in case of nickel, chromium, copper and arsenic, a very low capacity of heavy metals absorption was detected. *Typha latifolia*'s highest absorption capacity of heavy metals from the soil was recorded in case of cadmium.

Keywords: *absorption, bulrush, heavy metals, pollution*

INTRODUCTION

Heavy metals represent chemical elements which naturally belong to ecological systems, but they become pollutants after their exploitation begins [1 – 11].
Heavy metals constitute an important category of stable toxic pollutants. Unlike organic pollutants, metals are not biodegradable, they generally have little mobility and, for this reason, they persist in storage compartments (soil, sediments) for a long time. Metals are neither created nor destroyed by biological or chemical processes. These processes can only determine the transformation of the metal into different chemical species (the change of valence) or its conversion into inorganic or organic forms [12 – 20].
Table 1 presents the main industrial sources which generate heavy metals in the soil and the most important heavy metals [1 – 3, 11, 13, 21 – 23].

Table 1. *The main industrial sources which generate heavy metals in the soil and the most important heavy metals [1 – 3, 11, 13, 21 – 23]*

Industrial sources	As	Cd	Cr	Cu	Pb	Hg	Ni	Zn
Mining and processing of metal ores	+	+	-	+	-	+	-	+
Metallurgy	+	+	+	+	+	+	+	+
Chemical industry	+	+	+	+	+	+	-	+
Alloys industry	-	-	-	-	+	-	-	-
Paint industry	-	+	+	-	+	-	-	+
Glass industry	+	-	-	-	+	+	-	-
Pulp and paper industry	-	-	+	+	+	+	+	-
Tanning of hides and skins	+	-	+	-	-	+	-	+
Dyeing and textile printing	+	+	-	+	+	+	+	+
Chemical fertilizer industry	+	+	+	+	+	+	+	+
Petroleum refinery	+	+	+	+	+	+	-	+
Burning of coals	+	+	+	+	+	+	+	-

„+” sources which generate heavy metals;
„-” sources which do not generate heavy metals.

At the level of the soil, heavy metals are distributed, depending on the chemical state in which they find themselves, by means of surface fluxes, hydrologic infiltration fluxes towards the aquiferous layer and by means of fluxes towards organisms which take over substances from the soil by trophic means [1 – 3, 11, 13, 21 – 24].
Typha latifolia (Figure 1) is a plant species which accumulates heavy metals, so its investigation leads to significant results [7, 11].

Figure 1. *Typha latifolia*

The research aimed to determine the influence of anthropic activities carried out in Piatra Neamt city on the contents of heavy metals on the banks of Bistrita River. This influence was determined by analyzing the concentrations of heavy metals in the industrial area of Piatra Neamt city, Romania.

MATERIALS AND METHODS

The selection of sampling points with the aim of determining the concentration of heavy metals from the soil and plant took place in the areas where pollution sources are located.
Soil and plant samples were collected upstream/downstream of the industrial area of Piatra Neamt city (Figure 2).

Figure 2. *The location of sampling points on the banks of Bistrita River, upstream/downstream of the industrial area of Piatra Neamt city [11]*

The collected soil and plant samples had the following characteristics:
- soil:
  - clayey soils;
  - granulometry lower than 63 μm [25].
- plant:
  - *Typha latifolia* plant species (the popular bulrush);
  - root, stem, leaf.

Soil samples (was collected with core sample type devices, [25]) were taken at 10 cm deep in the soil, for three levels:
- minimum level: soil-water interface level of 0 cm;
- medium level: soil-water interface level of 50 cm, on the river bank;
- maximum level: soil-water interface level of 100 cm, on the river bank.

Typha latifolia samples were taken, including their roots, stalks and leaves, which were dried and then ground (the plants were harvested in July at the end of grow stage).

The determination of heavy metals was realized by atomic absorption spectrometry (AAS) technique using a ZEEnit 700 P spectrometer (Analytik Jena, Germany) [26].
All the reagents used for determining heavy metals from soil and plant were of analytical purity and were purchased from Sigma Aldrich (Germany).
Experiments were conducted in order to determine the concentration of eight heavy metals in the soil and plant, respectively for As, Cd, Cr, Cu, Hg, Ni, Pb and Zn (four replicates). The used methods were conformity with the standards [27 – 29].
Absorption capacity of heavy metal from soil in plant was calculated according to the formula presented in Equation 1 [11]:

$$C_{heavy\ metal\ plant} = \frac{Q_p - Q_s}{Q_s} \cdot 100\ [\%] \qquad (1)$$

where: $C_{\text{heavy metal soil}}$ – absorption capacity of heavy metal from soil in plant [%];
Q_p – concentration of heavy metals from plant [mg·kg^{-1} dry matter];
Q_s – concentration of heavy metals from soil [mg·kg^{-1} dry matter].

Figures 3 and 4 present the research methods employed for the determination of heavy metals contents in the soil and plants.

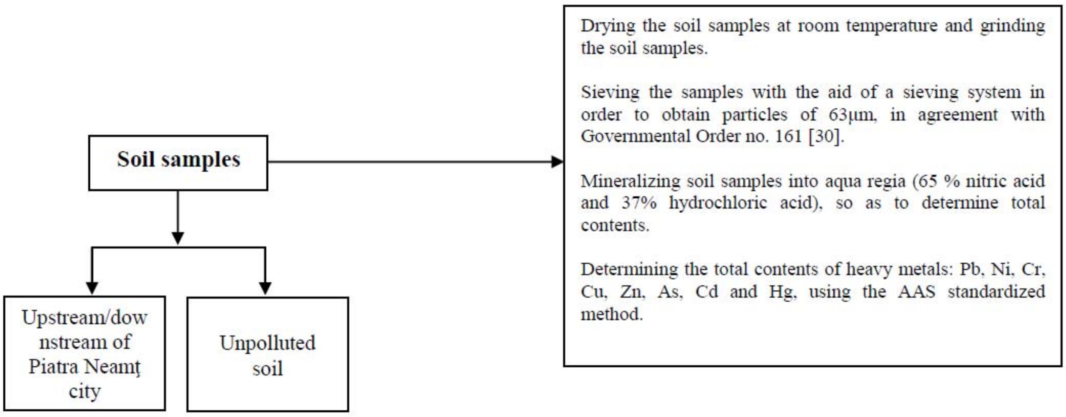

Figure 3. *Research methods employed for the determination of heavy metals in the soil [11]*

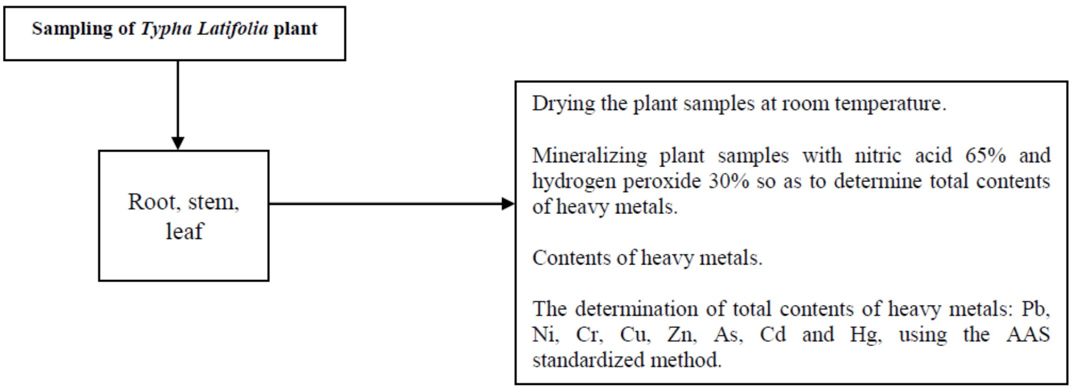

Figure 4. *Research methods employed for the determination of heavy metals in the plant [11]*

In agreement with Governmental Order no. 161 from February 16, 2006 [30], Table 2 presents the established maximum concentration levels for heavy metals in the soil.

***Table 2.** Elements and standards concerning the chemical quality of the alluvia [30]*

Quality indicator	Unit of measure	Quality standard
Cadmium	[mg·kg^{-1} dry matter]	0.8
Nickel		35
Chromium		100
Copper		40
Lead		85
Arsenic		29
Zinc		150
Mercury		0.3

RESULTS AND DISCUSSION

Table 3 presents the values for eight heavy metals determined by means of experiments for the witness samples of *Typha latifolia* plant and soil. The results obtained were under the standard value [30] demonstrating that the witness samples were unpolluted.

***Table 3.** Experimental values for eight heavy metals in the soil, respectively for the witness sample of Typha latifolia plant species from unpolluted soils*

Sample	Cd	Ni	Cr	Cu	Pb	As	Zn	Hg
	[mg·kg^{-1} dry matter]							
Soil	0.67	33	91	35	80	26	124	0.1
Typha latifolia Root + stem + leaf	0.024	0.797	0.472	4.607	0.399	0.03	14.03	0.009

Figure 5 represents the variation of heavy metals concentration in the soil and *Typha latifolia* (arsenic, cadmium, chromium, copper, mercury, nickel, lead and zinc) for the sampling point upstream of the industrial area of Piatra Neamt, at a minimum soil-water interface level (0 cm), respectively the values obtained for the witness sample.

The established maximum concentration limit for heavy metals in the soil for a minimum level of soil-water interface upstream of the industrial area of Piatra Neamt is exceeded in case of:

- nickel with 22.94 %;
- chromium with 41.3 %.

The established maximum limit for heavy metals in the soil for a minimum soil-water interface level is exceeded for (Figure 6, downstream of the industrial area of Piatra Neamt city):

- cadmium with 35.25 %;
- nickel with 2.45 %;
- copper with 51.62 %;
- zinc with 110.33 %.

A lower absorption capacity of heavy metals from the soil was recorded, for a minimum level of soil-water interface, upstream of the industrial area of Piatra Neamt, regarding *Typha latifolia* plant species, for nickel, chromium, copper and arsenic.
The absorption capacity of heavy metals from the soil for a minimum level of soil-water interface in case of *Typha latifolia* was much higher for the heavy metals below, as follows:
- for cadmium, the value determined in the plant was 973.66 % higher than in the soil;
- for zinc, the value determined in the plant was 249.18 % higher than in the soil;
- for mercury, the value determined in the plant was 61.76 % higher than in the soil;
- for lead, the value determined in the plant was 109.61 % higher than in the soil.

Figure 6 presents the variation heavy metals concentration in the soil and *Typha latifolia* plant species (arsenic, cadmium, chromium, copper, mercury, nickel, lead and zinc) for the sampling point downstream of the industrial area of Piatra Neamt city, at a minimum level of soil-water interface (0 cm), and the values obtained for the witness sample.
A lower capacity to absorb heavy metals from the soil was observed for a minimum level of soil-water interface in case of *Typha latifolia* plant species, downstream of the industrial area of Piatra Neamt city, for nickel, chromium, copper and arsenic.
However, the plant's absorption capacity of heavy metals from the soil, for a minimum level of soil-water interface, downstream of the industrial area of Piatra Neamt city, was higher for the following heavy metals:
- for cadmium, the value determined in the plant was 1043.25 % higher than the value in the soil;
- for lead, the value determined in the plant was 115.39 % higher as compared to the soil;
- for zinc, the value determined in the plant was 243.13 % higher than in the soil;
- for mercury, the value determined in the plant was 81.1 % higher than that in the soil.

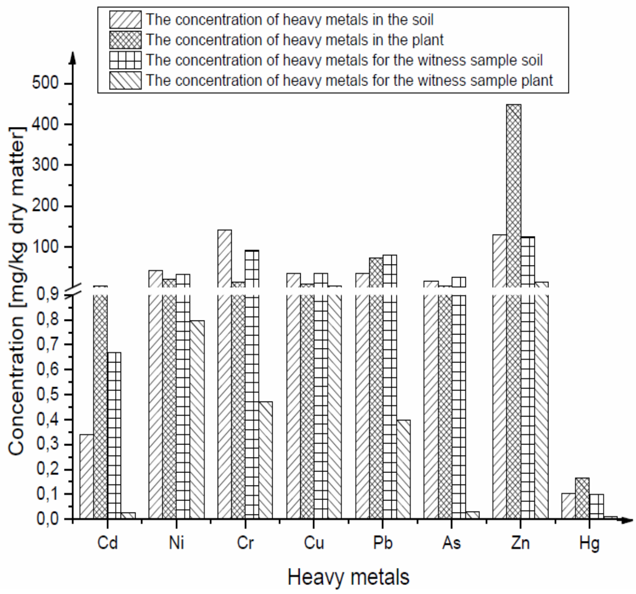

Figure 5. *The variation of heavy metals concentration in the soil, plant and the witness sample for sampling point upstream of the industrial area of Piatra Neamt, at a minimum level of soil-water interface*

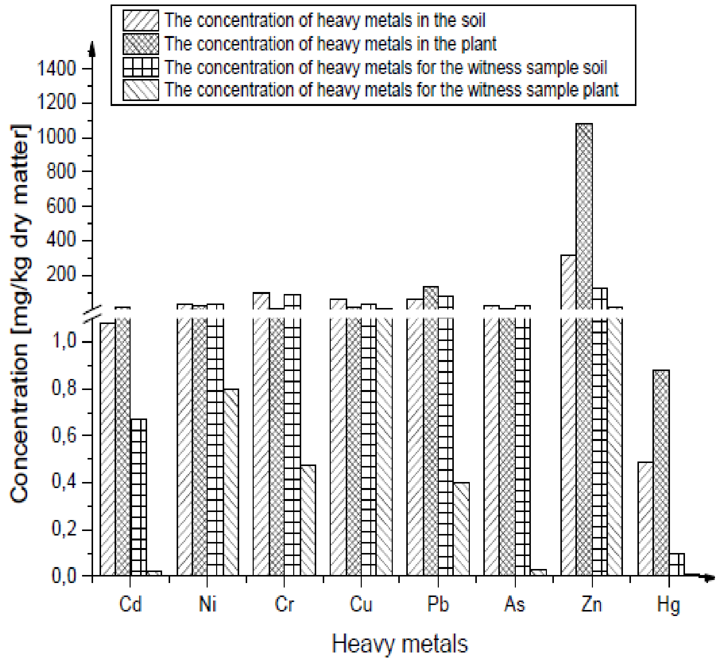

Figure 6. *The variation of heavy metals concentration in the soil, plant and the witness sample for the sampling point downstream of the industrial area of Piatra Neamt city, at a minimum level of soil-water interface*

Exceeding values recorded for heavy metals like nickel and chromium upstream of the industrial area of Piatra Neamt result from residual pollution caused by mining and industrial activities, the controlled or uncontrolled discharge of waste water which is cleaned inappropriately, the fertilization of agricultural land by means of fertilizers which contain heavy metals, the storage of human or animal waste, as well as the presence of stables and sewage systems or absorption pits in the area adjacent to the Bistrita River.

The established maximum limit for heavy metals in the soil for a medium soil-water interface level is exceeded for (Figure 7, upstream of the industrial area of Piatra Neamt city):

- nickel with 6.4 %;
- chromium with 54.93 %.

The approved maximum limit for heavy metals in the soil for a medium soil-water interface level is exceeded for (Figure 8, downstream of the industrial area of Piatra Neamt city):

- cadmium with 33.37 % ;
- nickel with 8.25 %;
- copper with 42.87 %;
- zinc with 117.33 %;
- mercury with 20.33 %.

Figure 7 represents the variation of heavy metals concentration in the soil and *Typha latifolia* (arsenic, cadmium, chromium, copper, mercury, nickel, lead and zinc) for the sampling point upstream of the industrial area of Piatra Neamt, at a medium soil-water interface level (50 cm), respectively the values obtained for the witness sample.

For the medium level of soil-water interface upstream of the industrial area of Piatra Neamt, the absorption capacity of heavy metals from the soil in case of *Typha latifolia* was much higher for the following heavy metals:
- for cadmium, the value determined in the plant was 837.91 % higher than in the soil;
- for lead, the value determined in the plant was 88.66 % higher than in the soil;
- for zinc, the value determined in the plant was 213.62 % higher than in the soil;
- for mercury, the value determined in the plant was 70.9 % higher than in the soil.

Figure 8 presents the variation heavy metals concentration in the soil and *Typha latifolia* plant species (arsenic, cadmium, chromium, copper, mercury, nickel, lead and zinc) for the sampling point downstream of the industrial area of Piatra Neamt city, at a medium level of soil-water interface (50 cm), and the values obtained for the witness sample.

A lower absorption capacity of heavy metals from the soil was recorded, for a medium level of soil-water interface, upstream of the industrial area of Piatra Neamt, in case of *Typha latifolia* plant species, for nickel, chromium, copper and arsenic.

For a medium level of soil-water interface, *Typha latifolia's* absorption capacity of heavy metals from the soil was much higher for the following heavy metals detected downstream of the industrial area of Piatra Neamt city:
- for cadmium, the value determined in the plant was 1122 % higher than in the soil;
- for lead, the value determined in the plant was 98.21 % higher than the value in the soil;
- for zinc, the value determined in the plant was 246.34 % greater than that in the soil;
- for mercury, the value determined in the plant was 80.6 % higher than the one in the soil.

For a medium soil-water interface level, *Typha latifolia's* absorption capacity of heavy metals from the soil was lower downstream of the industrial area of Piatra Neamt city, in case of nickel, chromium, copper and arsenic.

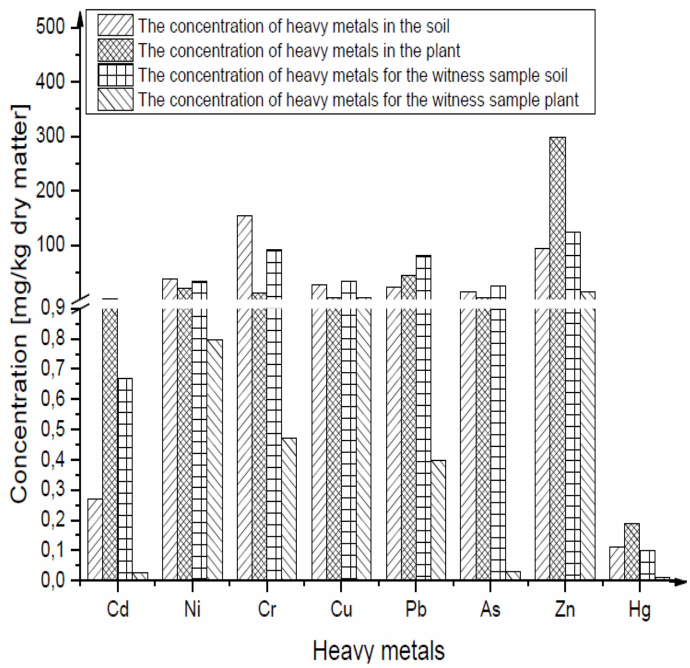

Figure 7. *The variation of heavy metals concentration in the soil, plant and the witness sample for sampling point upstream of the industrial area of Piatra Neamt, at a medium level of soil-water interface*

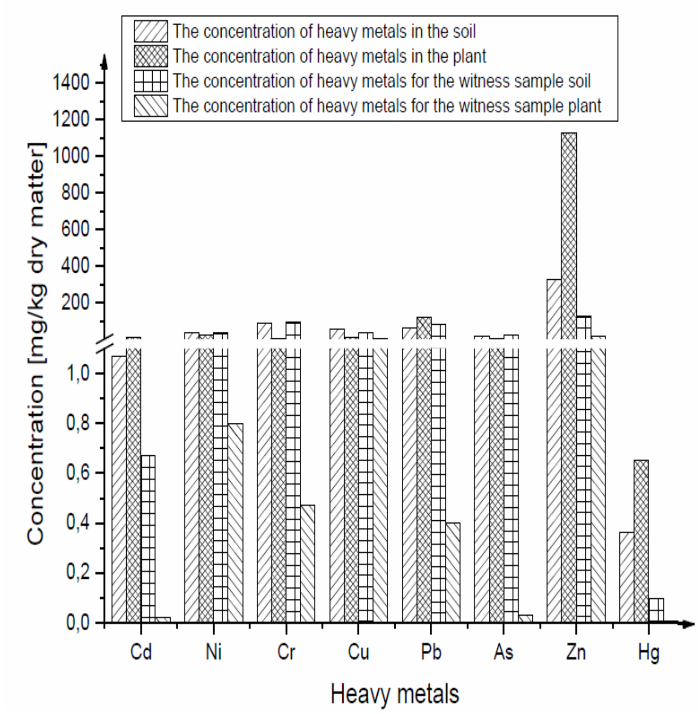

Figure 8. *The variation of heavy metals concentration in the soil, plant and the witness sample for the sampling point downstream of the industrial area of Piatra Neamt city, at a medium level of soil-water interface*

The established maximum limit for heavy metals in the soil for a maximum soil-water interface level upstream of the industrial area of Piatra Neamt is exceeded for (Figure 9, upstream of the industrial area of Piatra Neamt city):
- nickel with 21.71 %;
- chromium with 42.8 %.

The officially established maximum limit for heavy metals in the soil for a maximum soil-water interface level (Figure 10), downstream of the industrial area of Piatra Neamt city, is exceeded for:
- cadmium with 110.37 % ;
- copper with 17.95 %;
- zinc with 57.2 %;
- mercury with 194.33 %.

Figure 9 shows the variation of heavy metals concentration in the soil and *Typha latifolia* (arsenic, cadmium, chromium, copper, mercury, nickel, lead and zinc) for the sampling point upstream of the industrial area of Piatra Neamt, at a maximum soil-water interface level (100 cm), respectively the values obtained for the witness sample. A lower absorption capacity of heavy metals from the soil was recorded for a maximum level of soil-water interface in case of *Typha latifolia* plant species, for nickel, chromium, copper and arsenic.

The absorption capacity of heavy metals from the soil for a maximum level of soil-water interface, upstream of the industrial area of Piatra Neamt, in case of *Typha latifolia* was much higher for the heavy metals below, as follows:

- for cadmium, the value determined in the plant was 923.8 % higher as compared to the soil;
- for lead, the value determined in the plant was 86.74 % higher than in the soil;
- for zinc, the value determined in the plant was 254.66 % greater than in the soil;
- for mercury, the value determined in the plant was 77.67 % higher as compared to the soil.

Nickel, chromium and arsenic concentrations for the maximum soil-water interface level in case of *Typha latifolia* are more reduced than the values determined in the soil, in the sampling point downstream of the industrial area of Piatra Neamt city.

For a maximum soil-water interface level, *Typha latifolia's* absorption capacity of heavy metals from the soil was much higher for the following heavy metals detected downstream of the industrial area of Piatra Neamt city:

- for cadmium, the value determined in the plant was 878.48 % greater as compared to that in the soil;
- for lead, the value determined in the plant was 109.72 % greater than that in the soil;
- for zinc, the value determined in the plant was 256.02 % higher than the contents from the soil;
- for mercury, the value determined in the plant was 69.98 % greater than the value in the soil.

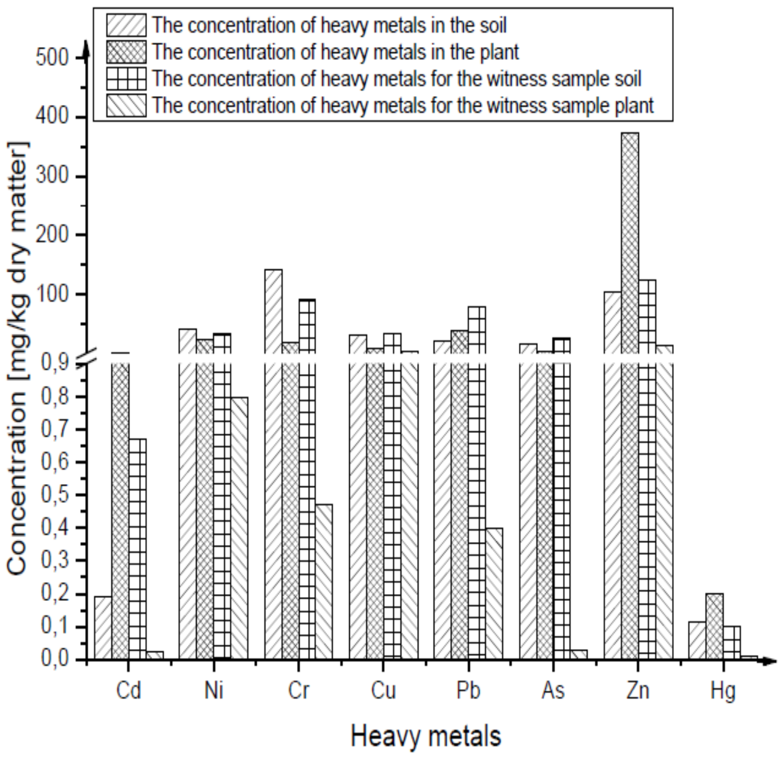

Figure 9. *The variation of heavy metals concentration in the soil, plant and the witness sample for sampling point upstream of the industrial area of Piatra Neamt, at a maximum level of soil-water interface*

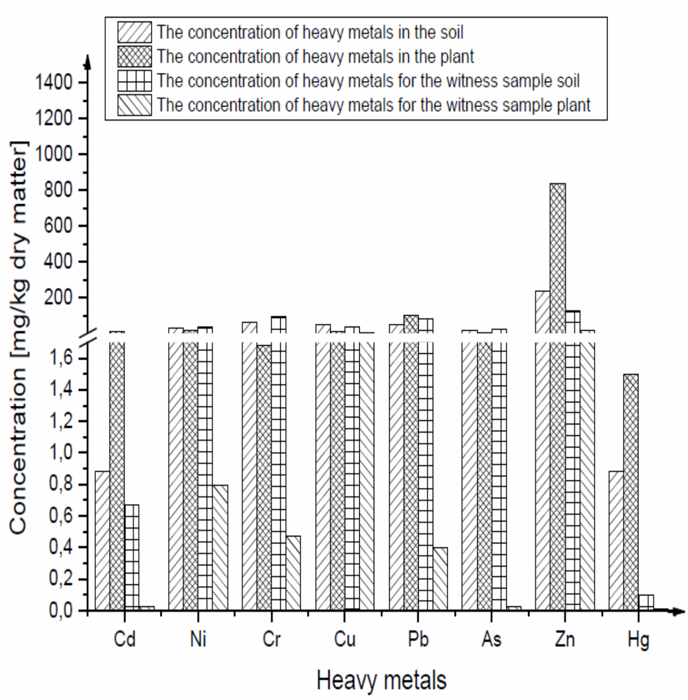

Figure 10. *The variation of heavy metals concentration in the soil, plant and the witness sample for the sampling point downstream of the industrial area of Piatra Neamt city, at a maximum level of soil-water interface*

Although the sampling point is located upstream of the industrial area of Piatra Neamt, residual pollution can be identified here, as well, as a result of pollution with cellulosic waste (which have a high contents of organic matter and heavy metals), produced by enterprises and cellulosic plants, or pollution with waste from the mining industry by means of points used for the extraction and preparation of iron, copper, nickel, manganese, zinc, copper, or sulphur ore, as well as the pollution with urban domestic waste water and refuse generated by agricultural and zootechnical sectors, which can be identified upstream of Piatra Neamt city.

CONCLUSIONS

It can be observed that the concentration values of heavy metals in soil, upstream and downstream from the city of Piatra Neamt varied as follows:
- for minimum level (soil-water interface level of 0 cm): the concentration of nickel in soil, downstream of the city of Piatra Neamt decreased compared to the value recorded in upstream;
- for medium level (soil-water interface level of 50 cm): the concentration of nickel in soil, downstream of the city of Piatra Neamt increased compared to the value recorded in upstream (because of the existing pollution sources);
- for maximum level (soil-water interface level of 100 cm):
  - ● the concentration of cadmium, copper and zinc in soil, downstream of the city of Piatra Neamt decreased compared to the value recorded in upstream;

● the concentration of nickel in soil, downstream of the city of Piatra Neamt increased compared to the value recorded in upstream (because of the existing pollution sources);

The investigation of *Typha latifolia*'s absorption capacity showed that, in case of nickel, chromium, copper and arsenic, a very low capacity of heavy metals absorption was detected. The experimental values obtained were much lower as compared to those detected in the soil samples.

For the same plant, a satisfactory absorption capacity was identified in case of heavy metals such as cadmium, lead, zinc, and mercury.

Typha latifolia's highest absorption capacity of heavy metals from the soil was recorded in case of cadmium.

Typha latifolia can be used in soil phytoremediation processes, particularly in phytoextraction processes (a method used for the removal of heavy metals from contaminated soils), since it is a very good accumulator of heavy metals on the harvestable side, on river banks, taking into account the expansion of the territory where these plants grow.

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