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Impact of Translocation and Bioconcentration of Heavy Metals in the Area of Lignite-Fired Power Plant

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Abstract

This study assesses the degree of trace metal translocation from the coal matrix (lignite) into slag and ash for the following metals: Hg, Pb, Ni, and Cd. Stored in heaps in the soil and plants from the local residential environment, near the power plant. Analysis of trace metals in the multicomponent sample was carried out by AAS. Within the coal, ash, and slag samples, as well as in the vegetation and soil surrounding the power plant's sphere of impact, heavy metals were discovered. For filter ash, RE Meiji ≈1 (Ni and Cd) and RE Meiji < 1 (Pb and Hg) indicate the enhanced metal level in the residues. Both Pb and Ni levels in the soil are higher than average, and Pb levels are also beyond the warning threshold for sensitive soils near garbage disposal (70.20 mg.Kg-1). The translocation factor (TF) indicates that the presence of heavy metals in soil and plants pushes Cd and Hg over the bioaccumulation reference value (Khan) of 0.5 and individual carcinogenic risk for Pb Ni Cd estimated at levels of: 10^{-7}; 10^{-6}; 10^{-5} relative to the WHO reference limit of 10^{-6}: it estimates a potential food safety risk.

Keywords: AAS, Heavy metals, Translocation, Bioconcentration, Lignite combustion, Power plant

Introduction

The quality of the environment can be impacted by thermal power plants, especially those that utilize coal as fuel. These facilities can occasionally have a significant impact on the ecological balance of the regions in which they are located. Ecological imbalances are produced in the environment and its quality by thermal power plants, especially those that use coal as fuel. Pollution stemming mostly from the generation of coal-based electricity has a complicated effect on all environmental components as well as the surrounding region, which includes air, water, soil, flora and fauna, food, and indoor spaces (Florescu *et al.*, 2011; Delia, 2015; Altıkulaç *et al*., 2022; Che *et al*., 2022). The surface coal extraction area from the Middle Jiu Basin and the thermal power plants in the area have undergone changes as a result of human action in large part: by uncovering the soil, an action necessary for surface mining of lignite and thus damaged the soil and its fertile layer, the large amounts of underground rocks that have been brought to the surface and which have led to the pollution of the environment with heavy metals and radionuclides, the formation of tailings, slag dumps and ash (Corneanu *et al*., 2013).

The main polluters with heavy metals in the area of action of coal-fired power plants are: combustion gases, ash from dumps, and the system of exploitation, transport and storage of coal.

Trace elements fall into three categories according to their effects on health or their concentration in coal, namely: negligible (Ag, Be, Ta, Te); minor (Na, Ba, Mn, Sr, Co, Ge, Sb, Cl, Li); moderate (Ni, Cr, Cu, V, Zn, F); major (Hg, As, Se, B, Cd, Mo, Pb) (Nalbandian, 2012). The influence of heavy metals (Cu, Zn, Mn, Ni, Pb, Cd, Co) on both the soil and the installations in the vicinity of the Turceni thermal power plant was analyzed and researched, aiming at the influence of polluting emissions of thermal power plants on acidity soil and heavy metal pollution of soil and plants (ICEMERG, 2000; Nica Badea, 2010). The emission of heavy metals from the coal matrix through combustion, the dispersion and transfer of some heavy metals in the soil, in cultivated plants and in medicinal plants from the spontaneous flora adjacent to the power plant, highlighted the fact that the metals detected in the coal samples are found in ash, slag, soil-plant distribution chain, in concentrations that do not exceed normal values or bioaccumulation limit values or that exceed the limits imposed by national regulations or literature reports (Bălăceanu *et al*., 2011; Turhan *et al*., 2020).

The content of heavy metals analyzed (total forms) from the population gardens, the crop fields around the thermoelectric power plant, the raw sterile dumps, the cultivated sterile dumps and the ash dumps exceeded the normal limits in most of the samples, in some cases they had values close to the limit alert or even intervention at a distance of 15-20 km north of the power plant in the public gardens (Corneanu *et al*., 2013; Mandal *et al*., 2022). The trace elements present in the carbon matrix through combustion are dispersed into the environment becoming hazardous trace elements that cause actual damage to human health and the environment (Wang *et al*., 2019). Even though they are found in trace amounts in coal (EPRI, 2010), these elements are thought to pose a health risk. As well as Cr, Hg, Mn, Ni, and Pb.

In this context, this paper presents the assessment of the level of translocation of trace metals Hg, Pb, Ni, Cd in the matrix of lignite in slag, ash deposited in dumps in the soil and plants from the local environment, reporting the concentrations determined at the data

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from the specialized literature, national and international standards.

Materials and Methods

Study Site

The Turceni thermal power plant is located in Lunca Jiului, GORJ county, Romania, south of the Jilţ stream, near it with Jiu River, approximately 1.5 km - E of the Turcenii de Sus locality. In regard to geomorphology, the thermal power plant's area of impact is part of the Getic Piedmont, which presents transitional characteristics between plains and mountains with respect to circumstances and resources, their exploitation, and the dynamics of settlements and landscapes. Its climate is mostly Mediterranean in nature, with air circulation in the Jiu corridor being disrupted in the NW-SE direction by circulation from the southern and western components. The mix of northwest Mediterranean climate and west coast oceanic air masses affects the temperature and precipitation regime. Forests, which reflect the natural vegetation, have steadily disappeared to make room for meadows and agricultural crops.

Turceni thermal power plant that is equipped with hot water and steam boilers represent an environmental pollutant. The primary air pollutants released into the environment include SO2, NOx, CO2, CO, unburned powders and particles, and heavy metal traces found in the gases produced when fuel and combustion air are burned in boiler hearths. The following are the primary potential sources of contamination to soil and subsurface areas: storage areas for coal, oil, and petroleum products; chemical storage; chemical water treatment plants; internal canals; and slag and ash storage. Emissions from the landfill may potentially reach the water due to the wet ash delivery system. The following are some preventive methods against soil and vegetation pollution: soaking slag and ash piles to stop wind from dispersing them; maintaining windbreaks made of sturdy trees and shrubs; and compliant temporary technical waste depots.

Sampling and Method of Analysis

Samples of soil and plant were collected carried out along the Jiu river corridor, between the towns of Țîntăreni and Valea Văii, in the NW-SE direction, taking into account the atmospheric circulation directions adjacent to the pollution sources (quarry, thermal power plant, solid waste) and the relief of the area. Soil samples (h = 20 cm), plant samples of which cereal samples were collected simultaneously. The features of the fossil fuel and the kind of solid wastes left behind from the technological process of burning coal (lignite) in the boilers of the Turceni thermal power plant, Gorj, respectively, served as the basis for the research methodologies used in the present investigation. Thermo Electron Spectrometer Model S Series AA SOLAAR, Flame Furnace, and Graphite ICPA Bucharest, a fully automated software platform, were used to analyze coal samples quantitatively for trace metals in accordance with ISO 11466:1999. Atomic absorption spectrometry was used to analyze the samples in accordance with international methodology and standards. The analysis of soil and plant samples, as well as the determination of Hg, was carried out using the VP Vapor 100 Kit generator, by atomic absorption spectrometry without thermal atomization, the cold vapor technique (CVAAS). AAS, the sampling and analysis technique, is distinguished by a number of excellent qualitative analytical characteristics for samples with multiple components. The technique is advised for heavy metal analysis of multicomponent samples from solid environmental samples (Ministry Order No. 756, 1997; Csuros & Csuros, 2002). The sensitivity ranges from 0.02-0.5 mg, and the detection limits (mg.L-1) are 0.005 for Zn and Cd, 0.04 for Ni, and 0.5 for Pb.L-

Results and Discussion

The global impact of pollutants on environmental degradation determines increased attention paid lately to monitoring and controlling the state of the surrounding environment. Combustion products from adjacent areas resulting from coal-fired power plants were analyzed in vegetables, fruits and herbaceous vegetation and biomonitored taking into account the degree of pollution. We began our investigation into the level of heavy metal concentration in main ash (at the level of filters), ash stored in the dump, soil, vegetation, and vegetable products of agro-food interest from the vicinity of a thermal power plant in accordance with solid fuel, coal, using data from the literature to assess the degree of heavy metal pollution **(Tables 1-5)**.

The results of this experiment were compared to the average values of trace metals published globally, as per the sources (China, Zhang *et al*., Australia). Swaine (Swaine, 1994), International Energy Agency IEA (Nalbandian, 2012), and coal (Romanian lignite) acquired in this experiment **(Table 1)** (Zhang *et al*., 2004). The experimentally determined heavy metal contents from Romanian lignite **(Table 1)** are shown below, along with a comparison to the literature: Hg, Cd, and Zhang (Zhang *et al*., 2004), as well as Pb and Ni, Nalbandian: IEA (Nalbandian, 2012) and Zhang, have values below the international level, whereas Hg, Swaine, and Nalbandian are within the range of global values (Zhang *et al*., 2004; Nalbandian, 2012). had values higher than those of the global average. This trace element content varies depending on the kind of coal, even within the same coal basin and across coals within the same basin. For instance, the lignite from the Schitu - Golești quarry has 18 ppm of lead, but the lignite from the Jilț-Gorj quarry has twice as much lead (31.40 ppm).

Table 1. Heavy metal concentrations in the analyzed samples (total forms)

Samples collected	**Hg ($mg \cdot Kg^{-1}$)**		**Pb ($mg \cdot Kg^{-1}$)**		**Ni ($mg \cdot Kg^{-1}$)**		**Cd ($mg \cdot Kg^{-1}$)**	
	c	sd	c	sd	c	sd	c	sd
Coal (lignite) n=3	0,020	0,012	31,40	0,87	30,30	0,98	0,331	0.32

Ash filters n=3	0,037	0,014	47,63	0,64	79,00	0,39	1,024	0.42
Ash, deposit slagn = 3	0,022	0,010	31,80	0,75	78,00	0,43	0,139	0.54
Soil bordering the warehousen = 6	0,102	0,02	70,20	3,69	45,2	11,24	0,302	0.12
Thermal boundary soil n = 6	0,049	0,022	40,00	2,23	40,8	12,0	0,254	0.12
Normal soil values	0,1		20		20		1	
Ground alert level[a]	1		50		75		3	
Warehouse vegetationn = 4	0,014	0,004	3,11	0,16	14,6	2,34	0,250	0.04
Vegetation bordering the warehouse n = 6	0,005	0,001	5,37	0,28	3,91	1,17	0,118	0.03
Bordering vegetation Termo n = 6	0,004	0,002	3.64	0,17	2,94	1,12	0,050	0.01
Permitted limits, vegetation	-		3-10		30		0,4	

c- average concentration; sd-standard deviation; a Soil sensitivity (Source: OM no. 756/19970)

Remainders are important wastes produced in massive numbers worldwide by power plants when coal is burned. Large volumes of coal ash are created and stored throughout the process of generating electricity from electric coal, which is a major problem since it has a negative impact on the environment and human wellness. 400 tons of ash and slag and about 1000 tons of coal may be used every hour by the 330 MW thermal plant (Cruceru *et al*., 2017). Using lignite as its primary fuel, the plant under investigation generates 7400 m3 of ash each day. **Table 2** shows the amounts of heavy metals (mg.Kg-1) in the ash analysis: Hg (0.037), Pb (47.63), and Ni (79.00). Comparing the determined concentrations of Ni, Hg, Cd, and Pb to the EU values of lignite fly ash (Moreno *et al*., 2005) (mg.Kg-1]: Hg (0.05), Pb (44), Ni (220), CD (2), it was discovered that the concentrations of Hg were greater.

Table 2. Heavy metal concentrations in Romanian lignite compared to other international reports

Heavy metals	**Experimental**	**Nalbandian**	**Swaine**	**Zhang *et al.***
	Medium values România(ppm)	**Medium values IEA (ppm)**	**Global Average Australia (ppm)**	**Global average China (ppm)**
Hg	0,020	0,03–0,19	0,02 – 1	0,12
Pb	31,40	1–22	2 – 80	25
Ni	30,30	1,5–21	0,5 – 50	15
Cd	0,331	0,01–0,19	0,1 – 3	0,6

Research indicates that in coal combustion facilities, solid products include enhanced traces of heavy metals (Bhangare *et al*., 2011; Vu *et al*., 2019). This enrichment is dependent on the kind of ash and the unique characteristics of each element (Meij, 1994; Meij & Te Winkel, 2009). Eq. 1 defines this procedure, which is followed in terms of quantification and relative enrichment (RE).

$$RE = [(Ash\ Conc./\ Coal\ Conc.) \times Crude\ Coal\ Ash\ Content\ \%]/100 \quad (1)$$

For the ash recovered at the bottom of power plant filters, displayed in **Figure 1**, the RE Meij enrichment factor values may be compared with other values reported in the specialist literature from China, India, and Canada using Eq. 1 and the 36% ash content in Romanian raw lignite (Goodarzi, 2006; Bhangare *et al*., 2011; Li, 2012). When compared to (Meij's Meij, 1994) categorization, the ash enrichment factors kept at the bottom of electrostatic precipitators arrange the metals examined in our study in the following order: Lead (0.54) and mercury (0.7) are in group III (very volatile, limited condensation, RE <1); nickel (0.94) and cadmium (1.1) are in groups I and II (non-volatile, respectively volatile, and condensation occurs, RE ≈1). In comparison to the fly ash collected by the filters, the trace metal concentrations found in the slag, bottom ash, and fly ash that are hydraulically carried to the deposit are somewhat lower (mg.Kg-1): 78.00 (Ni); 0.139 (Cd); 31.80 (Pb); and 0.022 (Hg).

The power plant, the ash deposit, associated technical processes, and the pedoclimatic features of the region work together to provide synergistic sources that facilitate the dispersion of trace metals for soil, vegetation, and agricultural crops in both rural and urban areas. The average Pb and Ni concentrations for the soil at the base of the ash deposit (mg.Kg-1) and the soil around the thermal plant (mg.Kg-1) are greater than the typical values, although they are still below the warning threshold for sensitive soils **(Table 3)**. The coefficient (Cn) is the ratio of the concentration found through experimentation to the normal soil concentration set by MO 756/1997. It is used to measure the degree of loading in relation to the accumulation and contamination of the soil with traces of heavy metals. Values of one represent a typical amount of pollution; smaller values indicate the lack of these components; and Cn greater than one indicates a high degree of contamination. The translocation factor (TF) has been commonly utilized in describing **Table 3** shows the Cn and TF values that were calculated for the ash deposit and the power plant's impact zone. It was found through studies that there is a high level of soil transfer (Cn) for Ni (2.2, 2.0) and Pb (3.5, 2.0). As evidenced by the values surpassing normal content (Cn) for lead (3.5) and even nickel (2.2), the level of ratios collected and reported in compliance with national regulations for referencing values of trace elements in soil further demonstrates the high rate of transfer. Reference (Ministry Order No. 756, 1997) Consequently, the lead content in the soil in the ash storage region (70.20 mg kg-1) is higher than the 50 mg kg-1 threshold set for vulnerable soils. The highest TF values for the plants under study **(Table 3)** are higher than the reference value. 0.5: The presence of Cd (1.9) and Hg (0.6) within the landfill, Hg (0.8) near the thermal plant, and even Cd (0.39) near the ash and slag deposit point to a bioaccumulation that has to be taken into account when assessing the effect on quality of life. The remaining TF values, which range from 0.005 to 0.19, are significantly lower than Khan's reference values (Khan *et al*., 2009), suggesting that the metals under study do not bioaccumulate.

Table 3. Availability of heavy metals in soil (Cn) and in plants (vegetation) (TF)

	Cn Ash storage area	**Cn Power plant area**	**TF Ash storage interior**	**TF Limitrof ash deposit**	**TF Limitrof thermal power plant**
Hg	1,0	0,49	0,6	0,05	0.80
Pb	3,5	2,0	0,1	0,07	0,09
Ni	2,2	2,0	0,2	0,08	0,06
Cd	0,36	0,25	1,9	0,39	0,19

Ash is the primary pollutant in the coal-fired power plant's sphere of effect. A solid contaminant that can be detected in aerosol form is made up of flying ash from chimneys, fine wind ash from slag and coal piles, wind-blown fine fly ash from slag heaps, and coal dust from coal storage, transit, and processing. To evaluate the effects of human activity on the environment using quality standards, it is vital to understand the geographical composition of soils and plants, as well as the variability and levels of trace element concentrations in them (Tanase *et al*., 2014). The degree of metal accumulation for distinct plant species, as well as its toxicity and tolerance, are indicated by the distribution of a metal species in its different forms as they migrate from the soil through plant parts, as represented by the transfer factor (TF), which is a function of numerous chemical and physical parameters (Khan *et al*., 2009; Kabata-Pendias, 2011). Within this framework, we examine the particular features of the soil's spatial distribution of heavy metals, as well as the possible anthropogenic pollutant caused by spontaneous vegetation growing alongside grain crops (barley and wheat) near the thermal power plant.

Heavy metals found in the composition of coal used as fuel were found in the composition of ash samples at the bottom of the plant's filters, in ash samples, in the soil and vegetation deposit and in the influence area of the power plant. All soil samples were within the range of maximum permissible limits (MPLs) for sensitive soils, according to national standards (Ministry Order No. 756, 1997).

The majority of the studied region has a Mediterranean climate, with airflow on the Jiului corridor being disrupted by circulation from the south and west in a northwest to southeast direction. The combination of the Mediterranean climate from the northwest and the oceanic air masses from the west affects the temperature and precipitation regime. Agricultural crops and meadows make up the majority of the natural vegetation. **Figure 1** displays the geographical distribution and the amount of heavy metal concentration in the soil next to the plant.

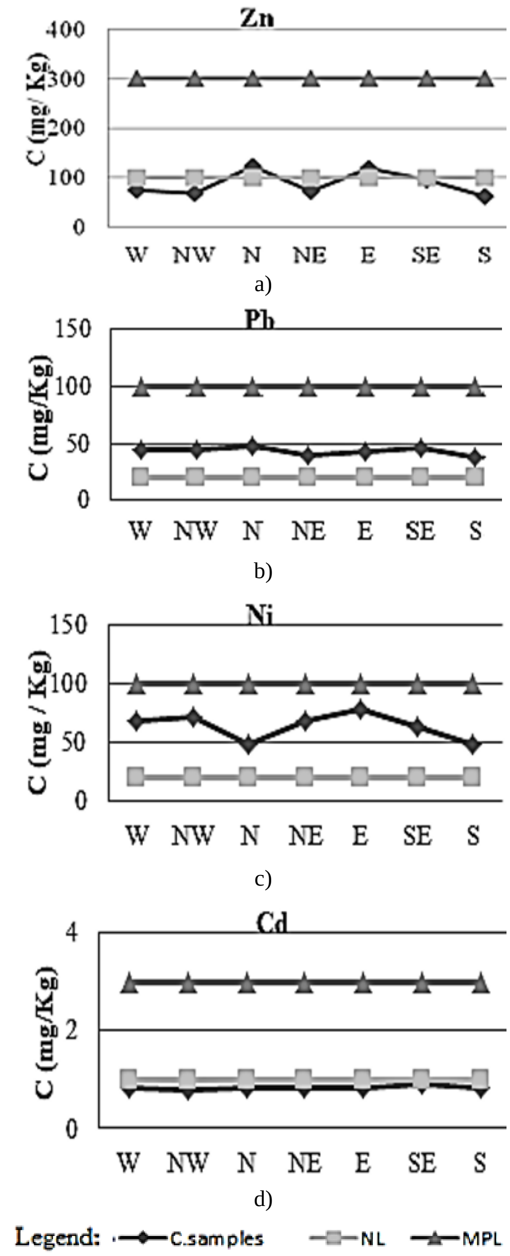


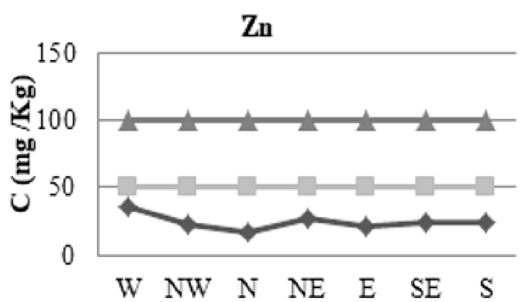
Figure 1. Spatial distribution of metals in soil: a) Zn; b) Pb; c) We; d) Cd

It can be found that the levels of heavy metal concentrations in the analyzed soil are placed above the normal levels established at the national level (Ministry Order No. 756, 1997), ($mg{\cdot}Kg^{-1}$):

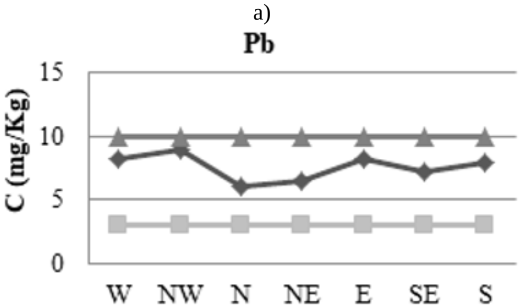
- The average value of Pb of 43.71 and Ni of 64.14;
- Maximum Zn value (123), profile direction N, characterized by clayey alluvial soils and pH 6.6 **(Figure 1a)**;
- Maximum Pb value (49.20), N direction profile, characterized by alluvial clayey carbonate soils and pH 7.4 **(Figure 1b)**;
- The maximum value of Ni (76.22), profile direction E, brown alluvial soils and pH 7.7 **(Figure 1c)**.

According to inspection of level I samples (16 × 16 km), the concentrations of heavy metals found in the soil near the thermal power plant are within the nationally validated range (Romania) for the elements and potentially polluting substances (PPES) in agricultural soil (Dumitru, 2000) (mg.Kg1): Zn (24.5 – 974), average values: 87.34 ± 61.4; Pb (4.9-335, mean values: 21.3 ± 18.6); Ni (4.2 – 171, average values: 34.49 ± 14.5); Cd (0.02 – 1.68, mean values: 0.43 ± 0.27).

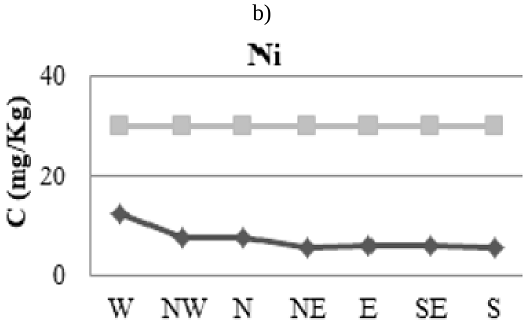
Figure 2b illustrates the spatial distribution of the concentrations of lead found in spontaneous vegetation. The values are near the maximum permissible limit (MPL2), which is comparable to the quantitative and spatial variation of lead in soil. Lead **(Figure 2b)** surpasses the lower permissible limit in all cardinal directions.1 11.



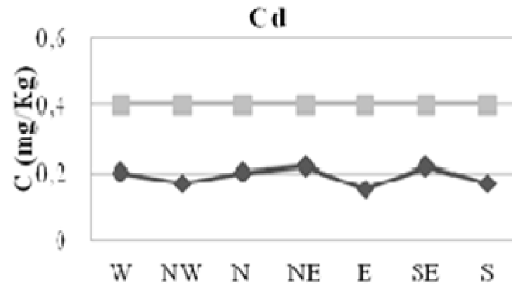
a)



b)



c)



d)

Legend: C samples MPL1 MPL2

Figure 2. Spatial distribution of metals in vegetation: a) Zn; b) Pb; c) We; d) Cd

Observing the concentrations of heavy metals in the vegetation, in general the maximum permissible limit is not exceeded, except for the slag deposit and its eastern base for Pb which is above the lower limit of the range with a concentration of 7.58 mg·Kg^{-1}, relative to national norms (3-10 mg·Kg^{-1}), **Table 4**.

Table 4. Metal content in plants (Average values, total forms)

Samples	Zn (mg·Kg^{-1})		Pb (mg·Kg^{-1})		Ni (mg·Kg^{-1})		Cd (mg·Kg^{-1})	
	c	SD	c	SD	c	SD	c	SD
Grassy vegetation	24.4	5.80	7.58	1.06	7.28	2.34	0.19	0.027
Standard [a]	50-100		3-10		30		0.4	
Wheat	22.96	4.92	7.51	0.78	6.58	1.97	0.175	0.03
Barley	24.25	4.74	8,75	0.82	8.00	1.98	0.170	0.03

[a] Source: MO 756/1997.
SD-standard deviation

The concentrations of heavy metals analyzed in plant products (agri-food) from the areas adjacent to the plant and the ash deposit are placed within or outside the permitted concentration limits by product category, depending on the reporting source in the literature. According to Pendias and Pendias (2001), the normal values for heavy metals in plants are (mg·Kg^{-1}): Zn 20-60; Pb 5-10; Ni 0.1-2.0); Cd 0.0-0.1, the average values that are exceeded by wheat and barley according to the experimental data in **Table 3**: Ni (6.58, respectively 8.00) and Cd (0.17, respectively 0.170). In accordance with the accepted international norms and standards for cereals, vegetable leaves and fresh herbs (Regulation, 2006; FAO/WHO, 2011), the limits allowed for concentrations in wheat and barley (mg·Kg^{-1}) are exceeded: for Pb with experimental values of 7.51, respectively 8.75, relative to the maximum allowed concentration of 0.2 and for Cd with experimental values of 0.175, respectively 0.170, average concentration, relative to a maximum permitted level of 0.1. The transfer factor (TF) calculated in for spontaneous vegetation in the area of wheat and barley crops analyzed, shows a moderate distribution of the level of heavy metals, ranging from 0.30 to 0.11 and from 0.27 to 0.11 for cereals grown in the same area. The transfer factor (calculated on the basis of average concentrations) decreases in the order: (a) Zn, Cd. Pb, Ni for spontaneous vegetation and wheat; (b) Zn, Pb, Cd, for barley.

Quantification of Individual Risk

The individual risk for Ni, Cd, and Pb may be computed based on average amounts found in soil (h = 0.25m) and plants (wheat). The following factors should be considered: It is believed that 100% of the land is used for crop cultivation (wheat), with 10% of the wheat being used in the contaminated area. The concentration due to the direct application of contaminants is zero, and the concentration because to transfer to grain is based on the absorption factor (UF) and soil metal concentration (Cs). **Table 5** presents the general information required to determine the individual risk factor for each of the three potentially harmful heavy metals (Pb, Ni, and Cd). Given that heavy metals are a class of persistent, indestructible pollutants that, when found in excess of a given concentration, have lethal effects on living organisms, monitoring of these pollutants is essential for assessing environmental safety and human health in particular (Batayneh, 2012; Cocârţă *et al*., 2016).

Table 5. Estimating the order of magnitude of individual risk.

Heavy metals	Comcentration in soil mg/kgd. w Average values	Slope factor (mg/kg/day)[a]	Individual risk order Ir
Pb	43.73	8.50×10^{-3}	10^{-7}
Ni	64.14	9.10×10^{-1}	10^{-6}
Cd	0.85	4.20×10^{-1}	10^{-5}

Even yet, the measured levels of Pb and Ni are above typical soil traces of about. The maximum individual risk score for Cd (10–5) was found at 50 and 60 times the excess of normal content (Cn), which is double that of Cd **(Table 5)**. This has been brought to light in two recent studies: (Ye *et al*., 2015), highlighting the high risk, and (Cocârţă *et al*., 2016), highlighting the high level of Cd (10–4) relative to Pb (10–6) and Ni (10–5). The WHO's individual risk index of 10–6, which was defined as the reference limit and used by (Dumitrescu *et al*., 2012), corresponds to one cancer case for every million exposed individuals. The evaluation of personal hazards, environmental safety, and particularly human health depend on the monitoring of these metals. In comparison to the WHO standard limit of 10-6, the individual risk for Pb, Ni, and Cd is assessed at levels of 10-7, 10-6, and 10-5 based on the average quantities found in soil and plants (wheat).

Conclusion

The environment is influenced by coal-fired power plants, even affecting the ecological balance of the areas where they are located, having a major impact on environmental factors (water, air, soil, food, flora, etc.). The toxic potential of traces of heavy metals resulting from the combustion products of the lignite matrix has negative effects on health and the environment. The environment in the area of power plants is anthropogenically loaded with various heavy metals, namely; lead, nickel, zinc, etc., but their concentration is maintained at moderate values due to the physico-chemical parameters of the soil, being less accessible to plants. This temporary state of fly ash contact has little impact on the soil and therefore on the plants. The evaluation of individual risks, environmental safety, and human health in particular depend on the monitoring of these metals since they are persistent, indestructible contaminants that have harmful effects on living creatures when their concentrations are above a specific threshold. The transfer and buildup of potentially toxic heavy metals in agricultural plants (crops, spontaneous vegetation), which pose a risk to the health of nearby town residents and raise concerns about food safety, makes the experimental results of this research relevant. As a result, the transfer is important, particularly when the pollution source is close to rural socioeconomic systems that are typified by subsistence farming, as this paper's example shows.

Analyzing the research results, can be summarized as follows:

- The amount of heavy metals that accumulate in soil and plants is not significantly impacted by the climate in the Turceni power plant region.
- Higher quantities of some metals are found in the flora close to the ash waste dump and power plant, according to experimental data on the content of heavy metals in that area.
- The synergism produced the following outcomes for the soil-plant system in the study area: the loading level of heavy metals and the spatial distribution: pedoclimatic and geomorphological features, lignite mining, transportation, and storage, lignite burning in the boiler, ash emission, and slag deposit ash as the primary causes of pollution.
- The studied heavy metal traces transferred from the coal matrix (36% lignite raw ash content) to the solid combustion products characterized by REMeij ≤1, are determined by the characteristics of each analyzed heavy metal content, of the ash, but also the technical characteristics of the system of burning brown coal.
- The amount of trace quantities of harmful heavy metals found in lignite, combustion products, soil, and plants close to emission sources indicates the potential for toxicity and the health risks associated with exposure. Therefore, based on national standards (MO 756/1997), the amount of concentration recorded in the area's soil surpasses normal norms (Pb and Ni) as well as reference values for sensitive soils (Pb).
- The availability of heavy metals in soil and plants, reflected by the translocation factor TF, places Cd and Hg above the reference value (Khan) of bioaccumulation (0.5), estimating potential food safety risk for Pb, Ni, Cd is at levels of: 10^{-7}; 10^{-6}; 10^{-5} compared to the WHO reference limit of 10^{-6}.

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Conflict of interest: None

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Ethics statement: Evaluation of the level of translocation of heavy metals with toxic potential from the coal matrix into solid combustion products and their bio concentration in soil and plants from the residential area adjacent to a thermal power plant: Turceni, Romania was carried out respecting the legal framework of the EU.

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