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ORIGINAL RESEARCH PAPER

SOURCE RISK ASSESSMENT FOR HEAVY METALS IN SOIL ON THE SITE OF A HYDROCARBON POWER PLANT

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Abstract: The present study aims to assess the soil quality on a hydrocarbon power plant site in Arad, Romania. It investigates the evolution of heavy metal concentrations (Cu, Zn, Pb, Ni, Cd, and Cr) to establish source-related risks. For this purpose, the Global Pollution Index (GPI) was used, calculated for soil sampling points in the licensed area, and the database of monitored indicators was processed. Sampling was carried out annually between 2011 and 2020. An Individual Pollution Index (IP_i) was calculated for each heavy metal and reference value, taking into account the Geochemical Background Level (B_i) specific to Romania. The correlation between these indices and the degree of pollution for each soil sample monitored was carried out to the legal provisions. Heavy metal concentrations (Cs, i) were evaluated in relation to the national legislation for less sensitive land use. Finally, the GPI was determined, and based on these values, the overall soil pollution status was assessed. Based on the determined CFi values and the corresponding Toxicity Factors (T_i) of heavy metals, the environmental impact was assessed by environmental risk analysis using the Risk Indices (ER_i and R.I.) method. All the analyzed indicators were within the legal limits during the studied period, except Cd, where the alert threshold was exceeded in 2019 and 2020.

Keywords: *anthropic source, contamination indexes, environmental risks, ground pollutants, monitorization indexes*

INTRODUCTION

Globally, soil is subject to contamination due to human activities [1], especially industrial ones [2], which have a significant impact [3]. Soil is not a renewable source relative to the human lifespan, and pollution is increasing. Prudent soil management is needed, given its fundamental role in providing ecosystem services essential to life, including as a global carbon sink [4].

Soil quality is a highly topical issue, as it is an essential factor in the formation and quality of water supplies. In a broad sense, soil quality can be seen as an indicator of sustainability, as it is an open and dynamic system configured on a highly complex matrix [5]. The sources of pollution are anthropogenic activities, with industrial activities playing a major role, as well as car traffic, especially in urban areas where car engine emissions pollute soils with heavy metals, especially lead.

Contaminants absorbed into the soil cause deterioration or loss of its functions, leading to cross-contamination of water [6]. Negative effects could be observed on plants and animals, which can seriously affect human health together with the food chain [7 – 9].

The issue of historically contaminated industrial sites due to past and recent industrial activities has gained particular attention in recent years. All Member States of the European Union must comply with the requirements imposed by the regulations of Community legislation. Romania's contribution to achieving its specific priority objectives has been established per the provisions of Art. 2 para. (1) of Decision No 1.386/2013/E.U. of the European Parliament and of the Council of 20 November 2013 [10].

Soil protection does not generally benefit from a specific regulation, as is the case for water or air protection. The method of achieving soil protection is through related regulations. At the national level, the level of soil contamination must be monitored according to the legal requirements in Ministerial Order 756/03.11.1997 [11].

Industrial energy production in thermal power plants generates significant emissions of activity-specific pollutants. The soil is subject to contamination, and the land around the power plants is affected by pollution, with a particular impact of persistent pollutants, including heavy metals, which have a toxic effect on the ecosystem and living organisms, accentuated by geo- and bioaccumulation processes [12 – 14].

Conventional fossil fuel-fired power plants largely meet electricity and heat demand. However, power plants face the great challenge of meeting environmental requirements while maintaining the high efficiency of combustion processes and reducing the lifetime of critical technological components.

The process of air-water-soil pollution in the case of an active thermal power plant, which emits gaseous pollutants and solid particles into the atmosphere due to the fuel combustion process, is systemic in a mutually conditioned circuit.

Atmospheric pollution is substantial through emissions of greenhouse gases and acidification, which over time produce acid rain. Together with heavy metal particles and particulates, this pollutes soil and water bodies, affecting their quality and, hence, the quality of ground and surface water supplies [15], contributing to soil pollution [16].

Accidental spills of products and wastes can also pollute the soil and thus lead to the migration of pollutants into the geological environment or the atmosphere through the evaporation of volatile components. In the operation of plants, transferring liquid hazardous substances from storage vessels to installations is a risk factor. Therefore, it must be carried out through appropriate piping networks in terms of tightness and resistance to specific corrosion, with maneuvers to ensure safe operation.

Heavy metals are genotoxic carcinogens for living beings. Their effect on human health and the environment is through concentrations in ambient air and deposition. Heavy metal compounds participate in the global transport of substances as aerosols in the upper atmosphere with micro and nano dimensions. There is no identifiable threshold below which these substances pose no risk to human health.

Metals are natural components that are part of global ecosystems. Some metals are essential for the normal functioning of living organisms, and others can be toxic to them, even at very low concentrations. Of all the metallic elements that exist in nature, 53 are heavy metals, with a density greater than 5 $g \cdot cm^{-3}$. They are often associated with pollution and toxicity, but some of them, such as essential metals, are absolutely necessary for living organisms but in low concentrations [17, 18].

The sources of heavy metals in the environment are varied and complex, of natural and anthropogenic origin [19]. The problem of the impact of heavy metals is accentuated by their effect on soil microorganisms, given that the soil is where most of the mineralization processes of organic residues are concentrated, which ensures the combination of biological and geological cycles. The persistence of heavy metals in the soil for long periods contributes to geoaccumulation and bioaccumulation. Soil is the interface of the ecological system of connections for the biosphere. In soil, the interaction between living and amorphous matter is highly dynamic. Metabolic processes involving the earth's crust, hydrosphere, atmosphere, and land-dwelling organisms, with soil microorganisms playing a pivotal role, are locked onto the soil matrix. Since soil can store twice as much organic carbon as vegetation, it plays a decisive role in climate change.

The study focused on the evolution of soil quality on the site of a natural gas-fired hydrocarbon power plant, which operated with fuel oil and coal in the past. Monitoring a group of heavy metals, namely copper, zinc, lead, nickel, cadmium, and chromium, served as a pollution fingerprint in the targeted industrial areas and underscored the importance of identifying and quantifying heavy metals in the soil. Soil quality monitoring is necessary and related to monitoring water and air quality in the site area. Operating the plant facilities in optimal parameters is essential, as is ensuring compliance with legal requirements for exploiting soil resources, including water resources, predicting the degree of associated risk, and avoiding events with negative environmental impact. To mitigate heavy metal pollution, it is strongly recommended to implement measures such as regular soil testing, implementing best practices for waste management, and promoting the use of clean technologies in industrial processes. When implemented effectively, these measures can significantly reduce heavy metal pollution and its adverse effects, providing a reassuring framework for environmental protection.

MATERIALS AND METHODS

Area of Study

Soil samples were taken from the site of the Hydrocarbons Thermofication Power Plant (CET Hidrocarburi) in the city of Arad, located in the western part of Romania. The industrial unit has operated on this site for 127 years. It was equipped with three single-phase generators, each being driven by a steam boiler. The sources of energy were variated over the years. Between 1897 and 1953, it used coal dust. Over the following ten years, it used fuel oil. In the next forty-six years, fuel oil and natural gas were combined. Since 2009, it has been exclusively combined with natural gas. The main activity of the plant is the combustion of fuels in installations with a total rated thermal input [P(tn)T] > 50 M.W., installations subject to the EU IPPC (Integrated Pollution Prevention and Control) Directive on industrial emissions (ref). The production capacities comprise four large combustion plants, two hot water boilers (HWB), and two steam boilers. The plant is currently in the process of technological restructuring, implementing a major new plant project, and modernizing the distribution networks.

Sampling

This study collected values for 120 soil samples from the authorized area, and the following parameters were analyzed as quality indicators: Cu, Zn, Pb, Ni, Cd, and Cr.
Sampling was carried out over ten years, from 2011 - 2020, on an annual basis. Identifying and quantifying heavy metals in soil can be a pollution fingerprint in the targeted industrial areas. The plant has strict soil quality requirements for the site area, imposed by the permit by national and European environmental legislation. It contains appropriate monitoring requirements for discharges of pollutants, specifying measurement methodology and frequency. Monitoring is carried out according to annual programs and stipulates, according to the Integrated Environmental Authorisation, namely *OM 756/03.11.1997, that the values of activity-specific heavy metal pollutant concentrations present in the soil of the company's land must not exceed the alert threshold for less sensitive land use and, recommended, must not exceed the values determined in 2008, according to the CET H Arad Site Report, carried out for obtaining the authorization.
The determinations were carried out according to officially approved methods. The methodology presented by Kowalska [20, 21] was applied to calculate the overall pollution index (OPI).
First, the Individual Pollution Index (IP_i) was calculated. This is used to determine the heavy metal that poses the greatest threat to the soil. It is determined independently for every examined heavy metal [20 – 22] according to the following equation 1:

$$IP_i = \frac{C_{i,s}}{GB_i} \tag{1}$$

where:
$C_{i,s}$-concentration of a heavy metal (i) in a point (s), $mg \cdot kg^{-1}$
GB_i-geochemical background level of the heavy metal in the study area, $mg \cdot kg^{-1}$.

The analysis considered the value of Romania's geochemical background level, a significant factor while calculating the individual pollution index (IP_i) [23].
Subsequently, the Ecological Risk (ER) can also be assessed.
(IP_i) levels are classified as follows: $IP_i \leq 1$ - unpolluted; $1 < IP_i \leq 2$ - low pollution level; $2 < IP_i \leq 3$ -moderate pollution level; $IP_i > 3$ - very high pollution level [24].

Individual assessment for heavy metals and general pollution status

These levels need to be equated by calculation with the values of Ministry Order 756/03.11.1997 for less sensitive land use.
Considering that the soil of the studied site is of industrial type, being legally classified according to Ministry Order 756/03.11.1997 in the category of less sensitive land use, we have calculated the corresponding individual pollution index (IPi) for the authorized values and also for the values initially determined in 2008, as provided in the Site Report CET H, to have an equivalent IPi comparison term (Table 1). Also, the classified IPi levels [24] and the expression of the Global Pollution Index (PLI) had to be reconsidered per the values allowed according to Ministry 756/03.11.1997 for the category of less sensitive land use, for a correct and adequate assessment.
The IPi levels, calculated based on the values provided in O.M. 756/03.11.1997 for less sensitive land use, serve as reference levels for Individual Pollution Indices. These results, explicitly reported in Table 1, are important in our assessment.
Concentrations of heavy metals ($C_{s,i}$) were assessed against national legislation for less sensitive land uses and against 2008 baseline determinations as per the permit. The results have been centralized in Table 2.

Table 1. *Results Individual Heavy Metal Pollution Index (IP_i) calculated based on legal reference values for CET H Arad*

Quality indicator	**Geochemical background value Romania (B_i) [mg·kg^{-1}] [25]**	**Sampling profile**	**Individual Heavy Metal Pollution Index (IP_i) calculated based on authorized reference values**			
			Location report CET H Arad. 2008		**Integrated environmental permit CET H Arad *Ministry Order 756/03.11.1997 for less sensitive land use**	
Heavy Metal		**Depth** [cm]	Measured values		Alert Threshold	
			$C_{i,s}$ [mg·kg^{-1} dry matter]	**IP_i**	$C_{i,s}$ [mg·kg^{-1} dry matter]	**IP_i**
Copper	0.36	**10**	34.10	94.72	250.00	694.44 ≤ CF_i≤ 1388.87
		40	40.70	113.05		
Zinc	0.60	**10**	87.50	145.83	700.00	1166.66 ≤ CF_i ≤ 2499.99
		40	96.20	160.33		
Lead	31.00	**10**	47.80	1.54	250.00	8.06 ≤ CF_i ≤ 32.24
		40	109.80	3.54		
Nickel	0.34	**10**	16.90	49.70	200.00	588.23 ≤ CF_i≤ 1470.57
		40	27.00	79.41		
Cadmium	1.11	**10**	1.70	1.53	5.00	4.50 ≤ CF_i≤ 8.99
		40	1.50	1.35		
Chromium	0.36	**10**	11.80	32.77	300.00	833.33 ≤ CF_i ≤ 1666.67
		40	20.30	56.38		

The analyzed indicators are within the legal limits throughout the studied period, except for Cd, which exceeded the alert threshold equal to 5 mg·kg^{-1} dry matter in 2019 and

2020 at both sampling profiles, recording values of 5.91 and 5.06 mg·kg^{-1} dry matter, at 10 and 40 cm depth respectively in 2019 and 5.40 mg·kg^{-1} dry matter, at 10 and 40 cm in 2020. Table 2 structures the results obtained, highlighting the situations that exceed the legislation specifications and the minimum (black bold) and maximum (red bold) levels registered in the period analyzed for each metal.

Table 2. *Heavy metal concentrations ($C_{s,\,i}$) values measured on the site of CET H Arad in the authorized area*

Quality indicator	**Sampling profile**	**Year**									
		2011	**2012**	**2013**	**2014**	**2015**	**2016**	**2017**	**2018**	**2019**	**2020**
Heavy Metal	**Depth** [cm]	**Concentration($C_{i,s}$)** [mg·kg^{-1} dry matter]									
Copper	**10**	28.6	22.8	23.1	22.7	27.3	**14.6**	34.1	37.0	23.0	**41.9**
	40	31.6	40.1	39.6	**40.7**	36.4	21.5	24.5	36.9	**19.7**	29.7
Zinc	**10**	164.1	74.8	75.0	71.8	67.5	87.5	**41.8**	**177.0**	62.6	146.0
	40	150.5	77.4	78.6	76.3	80.2	54.8	96.2	**160.0**	**54.0**	110.0
Lead	**10**	63.2	74.6	75.2	77.2	81.3	47.8	33.5	58.2	**15.1**	**83.6**
	40	17.5	**113.1**	112.9	109.8	104.6	52.1	29.4	86.7	**13.4**	102.0
Nickel	**10**	16.1	**6.4**	6.8	7.3	11.4	16.9	19.8	**27.0**	15.7	26.5
	40	17.5	12.1	**11.0**	12.4	16.1	27.0	12.5	**27.4**	14.0	25.0
Cadmium	**10**	**0.2**	**0.0**	**0.2**	0.9	0.8	1.7	0.9	0.4	**5.9**	**5.4**
	40	**0.2**	**0.2**	**0.2**	0.9	0.8	1.5	0.9	0.3	**5.1**	**5.4**
Chromium	**10**	2.4	**0.6**	**0.6**	0.6	1.6	7.3	11.8	23.8	16.3	**30.2**
	40	**0.6**	20.9	19.8	20.3	17.8	11.5	9.4	22.3	13.8	**22.4**

From the series of heavy metals assessed over the entire study period, we found that the alert threshold was only exceeded for Cd in 2019 by 18.20 % at the 10 cm depth profile and 1.20 % at the 40 cm depth profile, respectively, and in 2020 by 8.00 % at both depth profiles. In the case of the other heavy metals, there were no exceedances of the alert threshold, with all the values determined within the permitted limits. The highest values for almost all the contaminants were determined, especially in the last three years of the period considered, 2018 - 2020. The presence of lead in the samples analyzed may be determined by the use of coal as raw material to produce energy at the beginning of the unit activity [26].

The soil pollution degree was assessed by calculating the Global Pollution Index (GPI). This index shows the soil's heavy metal contamination level and is obtained based on the Individual Pollution Index (IP_i). The GPI is calculated as a geometric mean of the IP_i according to the formula:

$$\text{GPI} = \sqrt[n]{(IP_1 \times IP_2 \times IP_3 \times \ldots IP_n)} \tag{2}$$

where:

n - number of heavy metals analyzed;

IP_i - individual pollution index calculated for each heavy metal analyzed.

The Global Pollution Index (GPI) was calculated using the legal reference values authorized by Ministerial Order 756/03.11.1997 and the 2008 Plant Site Report to provide an equivalent comparison term for less sensitive land use types, as in this study. Then, the GPI was determined for the permitted area based on the soil samples taken from 2011 to 2020. The results are presented in Table 3.

Table 3. *Global Pollution Index (GPI) results for heavy metals calculated based on legal reference values for CET H and the values obtained on-site*

Depth [cm]	The Global Pollution Index (GPI) calculated based on legal reference values *Ministry Order 756/03.11.1997 for less sensitive land use										
	Alert Treshold	Year									
		2011	**2012**	**2013**	**2014**	**2015**	**2016**	**2017**	**2018**	**2019**	**2020**
10 cm	**155.98**	11.65	6.89	6.98	9.11	11.61	15.53	14.51	21.25	18.21	36.64
40 cm		7.57	16.39	16.00	21.67	20.06	17.75	15.13	20.05	13.36	32.17

The values obtained for the Global Pollution Index (GPI) based on soil samples taken annually from the authorized sampling area were compared with the GPI results calculated for the legal reference values. According to the GPI results for heavy metals obtained for the authorized area, no value exceeds the corresponding GPI value of 155.98 for the alert threshold, which is the permissible limit, indicating good soil quality on the site concerning heavy metal pollution during the period studied.
Based on the determined $C_{i,s}$ values and the corresponding Toxicity Factor (T.F.) for heavy metals, the environmental impact was assessed by the environmental risk analysis using the Risk Index method (EPR and R.I.). The toxicity factor values for heavy metals are given in Table 4.
The Individual Ecological Pollution Risk (ER) was calculated for the heavy metals studied based on the authorized reference values, applying the formula:

$$ER_i = CF_i * T_i \quad (3)$$

The results of the calculations based on equation (3) are presented in Table 4.

Table 4. *Results obtained for the heavy metal pollution (ER_i) based on the legal reference values for the site of CET H Arad*

Quality indicator	**Sampling profile**	**Toxicity Factor Value** (T_i)	**Individual Ecological Risk (ER_i) calculated based on authorized reference values**			
Heavy metal	**Depth** [cm]		**Location report CET H Arad. 2008**		**Integrated environmental permit CET H Arad** *Ministry Order 756/03.11.1997 for less sensitive land use **Alert Threshold**	
			($C_{i,s}$) [mg·kg^{-1} dry matter]	**(ER_i)**	($C_{i,s}$) [mg·kg^{-1} dry matter]	**(ER_i)**
Copper	**10**	5	34.10	473.60	250.00	3472.20
	40		40.70	565.25		
Zinc	**10**	1	87.50	145.83	700.00	1166.66
	40		96.20	160.33		
Lead	**10**	5	47.80	7.70	250.00	40.30
	40		109.80	17.70		

Nickel	**10**	5	16.90	248.50	200.00	2941.15
	40		27.00	397.05		
Cadmium	**10**	30	1.70	45.90	5.00	135.00
	40		1.50	40.50		
Chromium	**10**	2	11.80	65.54	300.00	1666.66
	40		20.30	112.76		

A comparative analysis of the results obtained for the Individual Ecological Pollution Risk of Heavy Metal Pollution (ER_i) in the period 2011 - 2020 on the site of CET H Arad with the reference values determined in 2008 was carried out, and the results are shown in Table 5. It structures the results obtained, highlighting the minimum (black bold) and maximum (red bold) levels registered in the period analyzed for each metal.

Table 5. *Results obtained for the Individual Ecological Risk of heavy metal pollution (ER_i) on the site of CET H Arad*

Heavy Metal	**Sampling point**	**Year**									
	CET H Arad	**2011**	**2012**	**2013**	**2014**	**2015**	**2016**	**2017**	**2018**	**2019**	**2020**
	Depth [cm]	**Ecological Risk of heavy metal pollution (ER_i)**									
Copper	**10**	397.2	316.9	320.8	315.3	379.2	**202.8**	473.6	513.9	320.0	**581.9**
	40	438.9	556.7	550.0	**565.3**	505.6	298.6	340.3	512.5	**273.6**	412.5
Zinc	**10**	273.5	124.7	125.0	119.7	112.5	145.8	**69.7**	**295.0**	104.3	243.3
	40	250.8	129.0	131.0	127.2	113.7	91.3	160.3	**266.7**	**90.0**	183.3
Lead	**10**	10.2	12.0	12.1	12.5	13.1	7.7	5.4	9.4	**2.4**	**13.5**
	40	2.8	**18.2**	**18.2**	17.7	16.9	8.4	4.7	9.1	**2.2**	16.5
Nickel	**10**	236.8	**94.7**	100.0	107.4	167.6	248.5	247.1	**397.1**	230.9	389.7
	40	257.4	177.9	**161.8**	182.4	236.8	397.1	183.8	**402.9**	205.9	367.6
Cadmium	**10**	**5.4**	**5.4**	**5.4**	34.3	21.6	45.9	24.3	9.3	**159.6**	145.8
	40	**5.4**	**5.4**	**5.4**	29.7	21.6	40.5	24.3	7.8	**136.5**	145.8
Chromium	**10**	13.3	**3.3**	**3.3**	3.5	9.1	40.5	65.7	132.2	92.8	**167.8**
	40	**3.3**	115.9	110.0	112.8	98.9	63.9	52.3	**125.0**	28.7	124.4

The General Ecological Pollution Risk (ER) was calculated based on the legal (authorized) reference values for the site of CET H by applying the formula:

$$ER = \sum ER_i \quad (4)$$

The results are centralized in Table 6 and 7. Analyzing the annual data calculated for the General Ecological Risk of Heavy Metal Pollution (ER) per site for the whole period studied, in comparison with the reference values determined in 2008, when the Site Report was made for obtaining the integrated environmental permit, we found that the determined values exceed these reference values only in two cases out of 10, namely in 2020, at the 10 cm depth profile, when the value of 1541.94 for ER was recorded, compared to 987.07, the value obtained in 2008. The second exceeded value was recorded in 2018 for the 40 cm depth profile, with ER equal to 1323.96, compared to 1293.59, the value obtained in 2008. The percentage of exceedances is not significant, except in the first case. It can be concluded that the results obtained show values that demonstrate a generally good evolution of the soil condition to the heavy metals in the series studied, these quality indicators having values that do not exceed the authorized limits, except in two cases, when the alert threshold for cadmium was exceeded. The general ecological risk of heavy metal pollution is very low, which is particularly important and gratifying, considering the 127 years of plant operation on this site, which involves burning fossil fuels in large combustion plants.

As the results shown in Table 7 indicate, even though the values obtained for the General Ecological Risk of Heavy Metal Pollution (ER) at the CET H site were exceeded twice, in the two cases mentioned above, the average value of the ER over the entire period studied was 12.36 % lower at the 10 cm depth profile compared to the 2008 reference calculated for the ER, and 23.83 % lower at the 40 cm depth profile compared to the same reference year. The lowest annual value recorded for ER at a 10 cm depth profile, compared to 2008, in the period studied, was obtained in 2012, being 557.02. The highest annual value recorded for ER at the 10 cm depth profile in the studied period was recorded in 2020, with a value of 1541.94. At the 40 cm depth profile, the lowest value recorded for ER in the period studied compared to 2008 was 736.84 in 2019. At 40 cm depth, the highest value for ER in the studied period compared to the reference year 2008 was 1323.96, obtained in 2018.

The results of the GPI index indicated that most of the samples are within limits allowed concerning the type of use for industrial land, of less sensitive use; the analysis of the results obtained proved a minimal impact on environmental factors in terms of heavy metals as well as the minimal existence of risks related to the source, in this case, the CET H ARAD. These promising results also indirectly demonstrate that, over time, the combustion processes have been run efficiently with satisfactory yields. Given that the site is located in a central area with a high population density, these results contribute to the health and tranquillity of the city, as the degree of soil pollution with heavy metals and other environmental factors is within normal limits.

***Table 6**. Results obtained for the General Ecological Risk of Heavy Metal Pollution (ER) at the CET H Arad site*

Location CET H Arad	**Year**										
	2008	2011	2012	2013	2014	2015	2016	2017	2018	2019	2020
Depth [cm]	**GENERAL ENVIRONMENTAL RISK OF HEAVY METAL POLLUTION (ER)**										
10	**987.07**	846.32	**557.02**	566.62	592.51	702.46	691.22	885.67	1356.77	909.94	**1541.94**
40	**1293.59**	958.55	890.43	976.35	1034.92	993.29	899.76	765.64	**1323.96**	**736.84**	1250.12

***Table** 7. Results obtained for the General Ecological Risk of Heavy Metal Pollution (ER) on the site of CET H Arad*

Period 2011-2020		**Results values determined during the study period compared to legal reference values cf. Site Report* Integrated environmental permit CET H Arad Year 2008**				
Total value **(ER)**	Average value **(ER)**	Average value **(ER)**	Lowest annual value **(ER)**		Highest annual value **(ER)**	
$\sum ER_i$			**Year**		**Year**	
S3 /10 cm depth **8650.47**	865.05	< 12.36%	557.02	**2012**	1541.94	**2020**
S3*/40 cm depth **9829.86**	982.99	< 23.83%	736.84	**2019**	1323.96	**2018**

CONCLUSIONS

The burning of fossil fuels in the power plant facilities has contributed to the accumulation of heavy metals over time in the soil of the investigated area to a certain extent. However, a decrease from the 2008 baseline values was found, with the average General Pollution Risk value in 2011-2020. The results indicate minimal source-related risks for heavy metals in the study area, except Cd. For Cd, the percentage of normal values is 80 %, with 20 % values exceeded at the alert threshold and 0 % for the intervention threshold, according to Ministry Order 756/03.11.1997 for less sensitive land use. We cannot exclude, without scientific research, the possibility of an external contribution from a significant source of pollution near the sampling area, at about 15 m, a national road artery with heavy car traffic positioned parallel to the southern longitudinal side of the studied site.
Studies and research are necessary to find solutions for protecting, preventing, and controlling environmental pollution in the context of sustainable development and by the legislation in force.

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The analytical data used were collected from documents uploaded to the official website of the National Environmental Protection Agency.

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