ORIGINAL PAPER

HEAVY METALS IN SOILS NEAR AN INDUSTRIAL PLANT IN GALATI, ROMANIA: IMPLICATIONS FOR THE POPULATION HEALTH RISK*

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Abstract. *Decades of industrial activity and popularization have developed many environmental pollution problems. Due to the toxicity and the ability of heavy metals to accumulate in the biota, pollution with these elements is a serious problem. An important difference between these metals and other pollutants is the fact that these are not biodegradable. Information about the total concentration of the heavy metal alone is not sufficient to assess the environmental impact, being necessary to find ways to explain the metal behavior. The current study characterizes the migration index and enrichment factor of trace metals nearby an industrial site from Galati city, Romania. The quantitative analyzes were carried out by nuclear related technique X-Ray Fluorescence (XRF) using a Niton XLt analyzer from 700 series and the following metals were chosen to be studied: As, Cr, Cu, Pb and Zn. These elements are specific pollutants for industrial sites; their concentrations exceed the legal norms in almost all the sampling points. The migration index (MI) value indicates a high or a low mobility of the element. Usually the MI depends on the pH values, the texture of the soil, the concentration of sulfur and (oxy)hidroxy Fe/Mn, the level of pollution etc. A high value of the enrichment factor (EF) indicates an anthropic origin of the metal. High values for EF where calculated for all the studied elements. These facts indicate that the pollution with As, Cr, Cu, Pb and Zn is serious and can affect the health of the population, by infiltrations in the underground waters and by atmospheric depositions.*

Keywords: *heavy metals, enrichment factor, migration index, industrial soil pollution.*

1. INTRODUCTION

The industrial soils can be considered as sinks of pollutants and sources of pollution, by transferring the heavy metals towards groundwater and into the food chain, ultimately to the human body. Usually the industrial activities are discharging important amounts of elements such as Cd, Cr, Cu, Pb, Zn into the environment. From industrial activities mainly is polluted the topsoil. Because of this, contaminated soil come into direct contact easily with the humans, especially children. Therefore it is necessary to apply a complete study of the enrichment level, in order to put restriction for some element emissions, and the migration index for the identification of the proportion of their mobile and bioavailabile forms [1]. Soil is affecting directly or indirectly the life quality. In general, anthropic activities such as industry, traffic, fuel combustion, waste disposal have an important contribution to the soil

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pollution. These activities are not affecting only the human life quality, but also the soil quality which is affected because of the appearing of salinity, erosion, compaction, and pollution [2]. A heavy metal contamination is very harmful for human body, because they slow the biochemical intercellular processes and are difficult to eliminate. Also, human exposure to heavy metals determines their accumulation in the fatty tissues, affecting the central nervous system and the internal organs, and the excess of lead to small children causes a decrease of IQ levels [3].

Because of the increasingly level of the pollution with heavy metals, worldwide analytical laboratories had developed many nondestructive atomic and nuclear spectroscopic techniques to evaluate the soil pollution, such as X-ray fluorescence (XRF) technique. XRF has a good accuracy, precision and sensibility offering very fast quantitative and qualitative information about 25 elements in soil samples [3].

2. MATERIALS AND METHODS

2.1. AREA OF SAMPLING

The soil samples were collected from the vicinity of Iron and Steel Works at Galati (Romania), which is one of the most important metallurgical complexes in the south-eastern Europe. The locations of sampling are presented in Table 1. The soil samples were taken from 0, 5 and 30 cm depth.

Table 1. Characteristics of prelevation points

Soil No.	Latitude (North)	Longitude (East)	Other characteristics
1a	45°23′4.6″	27°57′38.3″	Margin of Vadeni commune, Braila county
1b	45°22′27.6″	27°56′32.3″	Center, Vadeni commune, 150 m from railroad
2a	45°24′49.8″	27°56′27.2″	Sendreni commune, near slag dump of ISW
2b	45°24′31.3″	27°58′36.3″	Movileni village, Sendreni commune, near ISW South gate
3a	45°28′31.4″	27°55′44.6″	Mihail Kogalniceanu village, Smardan commune, Galati county
3b	45°27′19.4″	27°58′22.5″	Smardan commune, near ISW North gate

2.2. SAMPLE PREPARATION

The soil samples were air dried, sieved through a 250 µm sieve, encapsulated and quantitative and qualitative analyze of the heavy metals. In order to obtain the pH and conductivity values, was prepared a mixture of soil and water with a proportion of 1:2.5. The measurements were accomplished according to STAS 7184/13-88.

2.3. SAMPLE ANALYSIS

The elemental concentration was determined using XRF method, by employing an energy-dispersive Niton XLt 793 analyzer. The pH and conductivity were obtained using Consort Benchtop C862. The analysis where carried out at the Laboratory of European Excellence Centre for the Environment, Faculty of Sciences, University "Dunarea de Jos" of Galati. The results are presented in Table 2.

Table 2. Chemical and physical properties of the soil samples

Soil No.	Depth	As ($mg\ kg^{-1}$)	Cr ($mg\ kg^{-1}$)	Cu ($mg\ kg^{-1}$)	Pb ($mg\ kg^{-1}$)	Zn ($mg\ kg^{-1}$)	pH (units)	Conductivity ($\mu S\ cm^{-1}$)
1a	0	8.515	86.86	32.79	27.74	100.2	8.85	127.4
	5	9.09	85.35	32.02	23.87	92.798		
	30	12.48	82.55	29.48	17.35	68.552		
1b	0	10.07	74.13	25.06	18.71	79.456	8.66	170
	5	8.814	82.05	30.54	17.84	70.63		
	30	7.92	72.71	24.25	19.04	66.06		
2a	0	9.445	100.6	21.74	23.31	60.88	8.4	120.5
	5	9.193	90.15	23.68	20.82	62.03		
	30	11.04	83.77	27.47	16.93	55.76		
2b	0	9.89	52.99	21.02	52.24	121	8.84	122
	5	10.3	52.91	21.85	30.37	71.48		
	30	10.21	71.43	20.45	29.74	77.17		
3a	0	9.806	77.42	31.38	19.97	58.81	8.56	92.8
	5	10.03	95.16	29.89	15.46	54.59		
	30	8.836	77.45	34.2	16.47	46.4		
3b	0	8.765	101.3	24.7	29.07	72.69	8.37	102.9
	5	9.813	99.19	23.64	25.63	61.62		
	30	10.55	83.75	24.2	21.4	61.19		

In order to obtain information about the level of anthropic pollution it was calculated the enrichment factor according to equation (1):

$$FI = \frac{c_{obtained}}{c_{European\_average}} \qquad (1)$$

where $c_{obtained}$ represents the obtained elemental concentrations in this study and $c_{European\_average}$ is the European average elemental concentration, according to reference [4]. If the result is smaller than 1 the enrichment is low, if it ranges between 1 and 3 the enrichment is moderate, and if it is above 3 the enrichment is high [1].

The element index of migration value was calculated to evaluate the elemental degree of mobility using equation (2):

$$MI = \sum_{i=1}^{n} \left(\frac{c_n}{c_T} \right) \cdot d \qquad (2)$$

where n is the number of layers of the soil samples (3), c_n is the obtained elemental concentration for the n layer, c_T is the sum of the elemental concentration from all the soil layers, d the depth of the layer (0.3, 5, 30 cm). The obtained results can vary from 1, if the element concentration is found mainly in the first centimeter, and 30 if the element is found in the last 30 centimeters. The migration potential for the groundwater is classified in four classes [5]: A (<5 cm) very small, B (5-10 cm) moderate, C (10-20 cm) high, D (>20 cm) very high. All the results were obtained using Microsoft Excel application.

3. RESULTS AND DISCUSSION

By applying equations (1) and (2) on the obtained elemental concentrations (Table 2), there were determined the mobility index (MI) and enrichment factor (EF), presented in Table 3.

Table 3. The migration index and enrichment factor for the industrial soil samples

EF /MI	As	Cr	Cu	Pb	Zn
1a	0.92	0.98	1.83	0.99	1.43
	14.04	11.5	11.18	9.4	9.75
1b	0.82	0.88	1.55	0.80	1.18
	10.62	11.42	11.12	11.98	10.91
2a	0.91	1.06	1.23	0.87	0.97
	12.80	10.91	11.51	10.14	11.20
2b	0.93	0.68	1.85	1.61	1.47
	11.87	13.67	12.41	9.43	10.05
3a	0.88	0.96	1.41	0.74	0.87
	16.04	16.35	17.62	16.3	14.84
3b	0.89	1.09	1.39	1.09	1.07
	12.64	10.69	12.22	10.24	11.08

The results obtained for the enrichment factor revealed that location 1a, which is on the dominant direction of the wind (NV 80%), presents the most important enrichment of the study area. Locations 3a and 3b presented a moderate pollution because they are found on the opposed dominant direction of the wind. Elements that presented a moderate pollution are Cu, Cr, Pb and Zn. According to this result it is clear that the dominant direction of the wind is more important that the distance from the Iron and Steel Works.

The migration index is higher for location 3a, an agricultural site. This is due to the agricultural activities that take place seasonal, helping the elements to migrate into the soil profile. Also, an important factor is the soil morphology. Soil is weak to moderate alkaline, this concluding that pH does not influence the element migration. The elements are found to be of B or C class for groundwater pollution.

4. CONCLUSIONS

The level of pollution around the Iron and Steel Works is moderate. A close monitoring is recommended for elements such as Cr, Cu and Zn. These elements are involved in steel production, and local their concentrations have been found above the alert thresholds for sensitive soil. The mobility of the elements depends on the soil morphology and on the seasonal agricultural activities.

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