Assessing Soil Contamination in Recreational Areas of Western Romania Using the Composite Method for Urban Soil Risk Evaluation

Andra C. Gagiu[1], Mircea V. Mureșan[1], Luminiţa C. Pirău[1], Elena M. Pică[1], Camelia Botezan[2], Claudiu Tănăselia[3]

[1]Faculty of Materials Science and Environmental Engineering Technical University of Cluj-Napoca
[2]Faculty of Environmental Science and Engineering Babes-Bolyai University
[3]Research Institute for Analytical InstrumentationINCDO-INOE 2000 Cluj-Napoca, Romania

Abstract—The increase of anthropogenic activities has led to economic development. Scientific environmental researchers show that this may alter the quality of environmental factors such as air, water and soil. High concentrations of soil contaminates in urban areas have been highlighted in scientific studies and led to the conclusion that soil in Romanian cities may also be highly contaminated. The present study aims at assessing this hypothesis on four different cities in the western part of Romania. Soil samples belonging to recreational areas (parks and playgrounds) have been analysed using atomic absorption spectrometry. Elevated mean concentrations for As, Cu, Zn, Pb and Hg have been identified in all four cities included in the present research. The risks posed by recreational area soil contamination within these cities have been quantified and scaled using a novel calculation method and recommendations for its further use have been highlighted.

Keywords—component; urban soil, contaminants, risk calculation method

1. INTRODUCTION

The increase of anthropogenic activities has led to economic development. Nevertheless this often came at the cost of environmental pollution. In urban areas, increased human activities have resulted in enhanced emissions from different sources such as industry, transportations and domestic activities [1]. Scientific environmental researchers show that this may alter the quality of environmental factors such as air, water and soil. The interest in assessing urban soil contamination has developed recently as connected to potential risks that it may pose for the health of inhabitants. It has been stated that urban living is influenced at a large extent by the environment [2]. Elevated concentrations of soil contaminates in urban areas have been highlighted in scientific studies [3], [4], [5] and led to the conclusion that soil in Romanian cities may also be highly contaminated [6]. In order to probate this conclusion contaminates concentrations in soils of four western urban Romanian settlements have been measured. The study focuses on recreational areas as in this type of environment children come in contact most often with contaminates in soils. The risks implied have been assessed and scaled.

At international level an impressive number of methodologies exist in order to assess risks generated by contaminated soil. The BRGM – M.E method elaborated by the Bureau for Geological and Mining Research [7] was studied, assumed and adapted in order to quantify and analyse the risks associated with soils from recreational areas [8]. The resulting method was entitled the Composite Method for Urban Soil Risk Evaluation [8]. This study assesses risks posed by soil contamination in the recreational areas of Western Romania using the above mentioned method. Certain conclusions referring to their appropriateness and applicability of the method will be redrawn. The advantages and disadvantages of the method will be presented in the section dedicated to conclusions.

The study was carried out on 20 recreational areas, parks and playgrounds from county capital Western Romanian cities. 9 different metals (As, Cu, Cd, Zn, Pb, Hg, Co, Ni, Mg) were considered for analysis for each individual location. Anthropogenic pollution is frequently associated with these metals and their presence in the soil of recreational areas is considered a risk factor to health. The four cities considered for the analysis are Oradea, Arad, Timisoara and Baia Mare. Higher contamination is expected in the recreational areas of the city of Baia Mare as compared to the others. The reasoning behind this hypothesis is that the city of Baia Mare is well known for urban contamination due to the intense mining activities that have been carried out in the area.

The main research objectives of this case study consist in assessing the degree of contamination of soil in recreational areas of western Romania and to quantify risks using a novel approach on the matter. Also the limitations of the method shall be identified and discussed. Proposals for its application will be made in order to serve for future scientific studied or for environmental decision makers in Romania.

2. MATERIALS AND METHODS

2.1. Description of the studied Western Romanian cities

The soil samples from the urban recreational areas (public parks and playgrounds) analysed in the present study was taken from 20 parks and playgrounds situated in major cities within the Western territory of Romania. The cities chosen for the present study are Arad, Timisoara, Oradea and Baia Mare. These cities are county capital cities and are considered representatives because they are the biggest and the most inhabited within the geographical area chosen. All of the cities studied in the present research have over 100000 inhabitants, respectively: Arad 164208, Timisoara 307561, Oradea 204358 and Baia Mare 137455 as stated by the National Institute of Statistics. Intense industrial activities have been recorded in the city of Baia Mare as it is well known for the former mining industry that has functioned within the area for decades.

The 4 cities chosen for the study and their positioning can be seen in "Fig.1."

Fig. 1. Cities selected for the present study (adaptation of Google Maps)

2.2. *Sampling procedure and chemical analysis*

Input data for applying methodology had to be procured in order to quantify the metal pollution of recreational areas and the risks represented in these areas by soil contamination. Thus, 60 soil samples were collected from 20 different recreational areas and these were analysed to identify As, Cu, Cd, Zn, Pb, Hg, Co, Ni and Mg concentrations. Soil sampling was conducted based on recommendations within scientific profile publications and following the requirements stipulated in Order 184/1997 of the Ministry of Waters, Forests and Environmental Protection. In order to reduce sampling errors additional precaution measures were taken during sampling and preparation phase [9] aiming to limit external contamination and assure the integrity of existing contaminates [10]. Three soil samples have been collected from each location and roughly mixed. A quantity of less than 1 g was separated by repeated quartering [11]. All gathered samples were surface samples collected from the first 15 cm of soil. After being collected and air dried, the moisture and organic material was eliminated using a drying chamber at 110 degrees C. After, the samples were prepared for analysis by being dissolved in a royal water solution (3 parts HCl: 1 part HNO_3) and contaminate concentrations have been determined in using atomic absorption spectrometry. The concentration resulted for each metal in the soil samples has been included in the calculation method in order to quantify risks and soil contamination for each analysed recreational area. Also, additional information such as land surface, nearby existing sources of contamination, frequency of use of the recreational area, type of persons using it and their access to contaminants was gathered for the same reasoning.

2.3. *Pollution and risk quantification methodology*

Risk assessment is defined as the process of estimating the potential impact of a chemical or physical agent on human health or on an ecological system under a specific set of conditions [12], [13]. Risk assessment methods vary and generally imply phases or qualitative and quantitative dimensions. They are adapted in regards with legislation, purpose of use, the degree of complexity and the expertise of the developers [14]. In order to quantify soil pollution with metals and the risks associated, were calculated using The Composite Method for Urban Soil Risk Evaluation. This method absorbs the principle of the BRGM – M.E. method elaborated by the Bureau for Geological and Mining Research – BCGM [5], but it is modified to fit the specific characteristics of the recreational areas. The method implies granting values from 0 to 3 for 8 different parameters according to certain assessment grids and applying an arithmetic formula to calculate the risk coefficient. The used formula is: Risk = (A+B+C) x (D+E+F+G+H) and the parameters used in this calculation are: A – potential hazard - related to the soil, B – surface of the area taken into consideration, C – determined impact – related to the soil, D – existing sources of contaminants, E – protection barriers, F – access to contaminants, G – population present in the area taken into consideration and H – type of population. The scale for assessing risks rages between 1 and 255.

3. RESULTS AND DISCUSSIONS

Descriptive statistics for contaminate concentrations in soils of 20 urban recreational areas of Western Romania expressed in mg/kg are presented in *table I*. This set of data was obtained after the exploratory analysis of the concentrations of As, Cu, Cd, Zn, Pb, Hg, Co, Ni and Mg in the 60 park and playground samples analysed.

Table 1 - DESCRIPTIVE STATISTICS

Contaminant	Min	Max	Mean	St. Dev	Normal values for Romania
As	18.83	74.71	31.61	12.58	5
Cu	13.94	156.92	54.02	35.60	10
Cd	0.16	2.25	0.53	0.58	1
Zn	55.77	433.79	161.49	92.79	100
Pb	12.22	570.83	99.63	140.59	20
Hg	0.25	5.04	0.73	1.04	0.1
Co	6.27	13.90	10.01	1.96	15
Ni	15.67	43.65	28.78	7.93	20
Mn	459.7	1262.5	790.06	225.42	900

The average contamination exposed identified for As, Cu, Zn, Pb and Hg in the recreational areas analysed reveals highly enriched values compared to the normality thresholds set for Romania. The mean value recorded for As, Cu and Pb was calculated as being approximately five times higher than the values established for uncontaminated soils in Romania. Therefore, it can be stated that these are contaminates that contribute more to risks related to urban soil contamination in the four cities analysed.

For these contaminates the minimum, maximum and average was calculated for each city individually and results are expressed in *tables II to VI*.

TABLE II. MINIMUM, MAXIMUM AND AVERAGE VALUES FOR As [mg/kg]

City	Min	Max	Mean
Arad	24.42	30.80	28.83
Timisoara	18.83	29.51	25.38
Oradea	24.18	50.85	34.33
Baia Mare	24.75	74.71	47.21

TABLE III. MINIMUM, MAXIMUM AND AVERAGE VALUES FOR Cu [mg/kg]

City	Min	Max	Mean
Arad	18.45	52.40	37.85
Timisoara	13.94	87.76	33.91
Oradea	28.95	80.04	57.37
Baia Mare	26.07	156.92	95.39

TABLE IV. MINIMUM, MAXIMUM AND AVERAGE VALUES FOR Zn [mg/kg]

City	Min	Max	Mean
Arad	55.77	272.22	157.19
Timisoara	81.68	158.25	120.39
Oradea	87.32	210.64	158.42
Baia Mare	61.64	433.79	257.86

TABLE V. MINIMUM, MAXIMUM AND AVERAGE VALUES FOR Pb [mg/kg]

City	Min	Max	Mean
Arad	12.22	58.11	35.37
Timisoara	21.61	66.23	39.05
Oradea	27.70	208.51	120.80
Baia Mare	25.04	570.83	302.90

TABLE VI. MINIMUM, MAXIMUM AND AVERAGE VALUES FOR Hg [mg/kg]

City	Min	Max	Mean
Arad	0.25	0.44	0.34
Timisoara	0.26	1.08	0.51
Oradea	0.34	0.63	0.70
Baia Mare	0.25	5.04	2.23

The same tendency can be observed for all four cities analysed. As expected the recreational areas in the city of Baia Mare are the most contaminated, followed by the recreational areas in Oradea. The cities of Arad and Timisoara are less contaminated but the average for each contaminate analysed oversees considerably the normality thresholds established for Romania. In this case, elevated concentrations due to naturally enriched soil cannot be applied.

Correlation coefficients between the identified concentrations in the 60 samples have been identified in order to analyse relationships between contaminates. The results are presented in *table VII*.

TABLE VII. CORRELATION BETWEEN CONTAMINANTS

	As	Cu	Cd	Zn	Pb	Hg	Co	Ni	Mn
As	1.00								
Cu	0.75	1.00							
Cd	0.96	0.83	1.00						
Zn	0.70	0.87	0.76	1.00					
Pb	0.95	0.84	0.97	0.77	1.00				
Hg	0.32	0.74	0.48	0.75	0.50	1.00			
Co	0.27	0.08	0.07	0.02	0.05	-0.35	1.00		
Ni	-0.24	-0.27	-0.41	-0.18	-0.34	-0.41	0.78	1.00	
Mn	0.66	0.32	0.52	0.33	0.45	-0.22	0.79	0.41	1.00

The Strong correlation between As, Cu, Cd, Pb and Zn have been identified suggesting that these contaminates are connected and their concentrations follow a direct proportional tendency. In this case elevated concentrations of one contaminate may indicate increased concentrations of the others.

The risk coefficient associated with soil contamination in recreational areas was measured using the Composite Method for Urban Soil Risk Evaluation. This is one of the criterion variables analysed in this study. It is a continuous variable with possible scores between 1 and 255, which divides recreational areas into 3 categories. The first category includes non-hazardous recreational areas with calculated risk values between 1 and 57. The second category comprises moderate risk recreational areas, namely those with scores between 58 and 103 and the third category includes major risk areas, namely scores above 103. Risk thresholds were calculated by relating the overall calculated score of the most hazardous scenario to the overall score and risk thresholds of the BRGM – M.E. method elaborated by Bureau de Recherches Géologiques et Minières, according to *table VIII*.

TABLE VIII. Risk threshold calculation related to the BRGM – M.E. method

	BRGM – M.E. method elaborated by Bureau de Recherces Geologique et Minieres	**Composite Method for Urban Soil Risk Evaluation**
Maximum possible score	135	255
Low risk potential	1-30	1-57
Moderate risk potential	31-55	58-103
High risk potential	55-135	103-255

Using the above mentioned algorithm risks have been calculated for the 20 recreational areas analysed in the four cities and classified in risk different classes. The results are presented in *table IX*, an expressed in “Fig. 2”. It can easily be noticed that the recreational areas that can be characterised as having high risk potential are the ones in the city of Baia Mare. These recreational areas need to be properly monitored by environmental decision makers and remediation methods should be applied. Moreover, until these types of actions can be implemented, the population that utilises these parks and playgrounds for recreational reasoning should be informed about the risks soil contamination poses. Taking into account that the most frequent exposure routes to contaminate in soil are: soil ingestion, breathing volatiles and dust and absorbing contaminates throw skin it is recommendable not to allow unattended children to utilise these recreational areas and to limit to minimum the time spent here.

TABLE IX. Risk assessment calculation

Recreational area	Total quantified risk	Risk classes
Arad 1	58.4	Moderate
Arad 2	48.8	Low
Arad 3	63.9	Moderate
Arad 4	40.5	Low
Arad 5	24.6	Low
Timisoara 1	64.8	Moderate
Timisoara 2	54.9	Low
Timisoara 3	54.9	Low
Timisoara 4	32.8	Low
Timisoara 5	76.5	Moderate
Oradea 1	36.9	Low
Oradea 2	64.8	Moderate
Oradea 3	72.9	Moderate
Oradea 4	54.9	Low
Oradea 5	49.2	Low
Baia Mare1	85	Moderate
Baia Mare 2	117	High
Baia Mare 3	36.9	Low
Baia Mare 4	127.2	High
Baia Mare 5	108.9	High

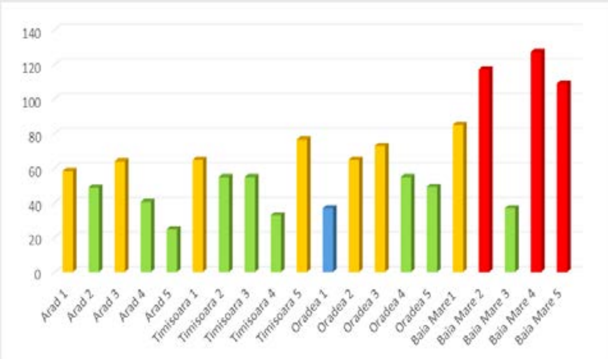

Fig. 2. Total quantified risk coefficient

4. CONCLUSIONS AND PERSONAL CONSIDERATIONS

The present study was elaborated in order to assess the degree of contamination of soil in recreational areas of Western Romania and to quantify risks posed by urban soil contamination using a novel approach on the matter.

The main types of pollution identified in the recreational areas are those with As, Cu, Zn, Pb and Hg. The average contamination identified for the above mentioned contaminates in the recreational areas analysed reveal highly enriched values compared to the normality thresholds set for Romania. The mean value recorded for As, Cu and Pb was calculated as being approximately five times higher than the values established for uncontaminated soils in Romania indicating serious urban soil pollution. As expected the recreational areas in the city of Baia Mare are the most contaminated, followed by the recreational areas in Oradea. The cities of Arad and Timisoara are less contaminated but the average for each contaminate analysed oversees considerably the normality thresholds established for Romania. Strong correlation between As, Cu, Cd, Pb and Zn have been identified suggesting that these contaminates are connected and their concentrations follow a direct proportional tendency.

The risk coefficient associated with soil contamination in recreational areas was measured using the Composite Method for Urban Soil Risk Evaluation.

This can be described as a more complex analysis method deriving from the BRGM – M.E. method elaborated by the Bureau for Geological and Mining Research (Bureau de Recherches Geologiques et Minieres), for analysing the risks associated with urban soil contamination. To apply the method, along with the recorded concentration of contaminants, a set of data such as analysed area, the usage frequency and access to potential contaminants concerning the analysed area also needs to be introduced. The analysis of the results shows that not all the strongly contaminated recreational areas are also highly hazardous recreational areas, but all the non-contaminated recreational areas are non-hazardous. Using this method only 3 of the 20 recreational areas analysed have been identified as posing high risks for the population that uses them. All three were located in the city of Baia Mare. This result reflects accurately the urban environmental reality and proves that it is important to quantify risks using a realistic method that keeps the level of risks in perspective. Nevertheless, it is clear that assessing risks based on a calculation requires more input data and a greater degree of resources. In this case its application is recommended in the more advanced stages of risk analysis because according to the generated results, informed decisions can be taken in respect of future actions.

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Andra C. Gagiu
Faculty of Materials Science and Environmental Engineering
Technical University of Cluj-Napoca
Cluj-Napoca, Romania
andra_gagiu@yahoo.com