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The effect of road and railway traffic on the soil quality from the Public Garden of Galati, Romania

Alina Sion[1,2*], Andreea-Cătălina Gîrmacea [3], Antoaneta Ene[1,2],
Mihaela Timofti [1]

[1] *"Dunarea de Jos" University of Galati, Faculty of Sciences and Environment, Department of Chemistry, Physics and Environment*
[2] *"Dunarea de Jos" University of Galati, Faculty of Sciences and Environment, INPOLDE research center, 800008 Galati, Romania*
[3] *"Dunarea de Jos" University of Galati, Faculty of Sciences and Environment, Master student at Environmental Monitoring and Management Program*
[*] *Corresponding author: asion@ugal.ro*

Abstract
In this article are studied samples of soil collected from Public Garden of Galați, Romania. This location was chosen to observe the negative influence of road and railway traffic on the soil quality. The soil samples were collected from the surface (0 cm), 5 and 30 cm, from the all four principal and secondary garden entrances and one sample from the playground area. The analytical method used to study the soil samples was X-ray fluorescence spectrometry (XRF), a non-destructive technique and very popular in environmental studies, that provided qualitatively and quantitatively information of the elements contained in soil. The results presented a strongly negative influence on soil quality from the road traffic, but the railway traffic didn't have a strong impact on the soil quality because it was related to person transfer.

Keywords: soil, park, XRF, non-destructive analysis, road traffic, railway trafic.

1. INTRODUCTION

In urban areas, traffic represents a point and linear source of pollution with multiple negative impacts on the environment. In the last decades it increased exponentially with a high human health impact, due to the risk of accidents, and a high environmental footprint as a source of many harmful substances.

Transport, in any form (land, sea, air), is essential for economic development, providing access to jobs, services and ensuring people's mobility and transport of goods. In Europe was estimated that 75 % of goods are transported by road, 19 % are using the rail and the rest of 6 % uses the transport on water. For passenger transport up to 96 % are using the road and a maximum of 17 % are using the rail.

The impact of transport on environment is soil erosion from the removal of the land surface to construct roads and soil contamination with different types of pollutants. Some of the processes by which vehicles emit heavy metals (Pb, Zn, Cu, Cd, Ni etc.) into the environment are combustion processes, machine wear, oil spills and corrosion. For example, lead is spread by burning leaded gasoline; zinc comes from tire dust, brackets, oil leaks, radiator, and copper results from brake abrasion and radiator corrosion; chromium sources are tires and brackets etc. The accumulation of heavy metals in soil is a threat because these pollutants are not biodegradable, and have the ability to bioaccumulate and biomagnify. In soils the accumulation of pollutants can alter the soil pH and with it the physicochemical and biological properties [1–5]. The common definition of heavy metals includes the elements with density higher than 5 g cm^{-3} or with atoms weight greater than 40. In total 38 heavy metals are known, from which, in low concentration, some are elemental for the living organisms (e.g. Cu, Fe, Mn and Zn), and others (e.g. Cd, Hg and Pb), regardless the concentrations, are very toxic [6,7].

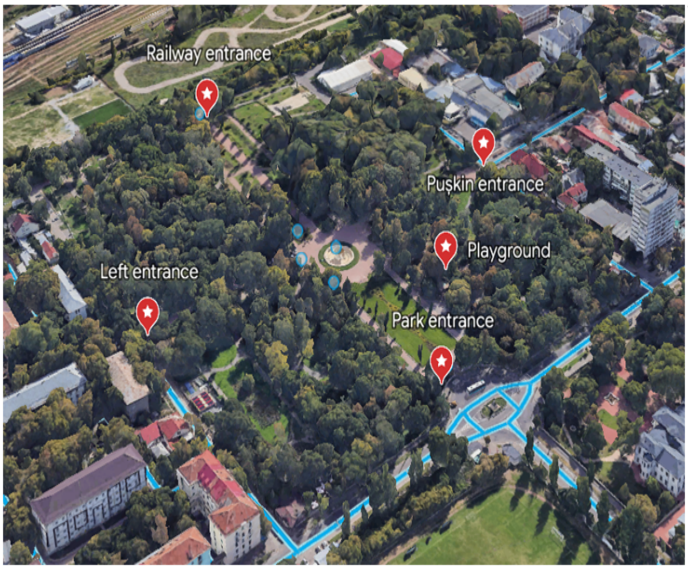
Soil metal pollution is also a phenomenon caused by railway traffic, especially through emissions of Fe, Hg, Ni, Cd, Pb, Cu, Zn and Cr that can be found in concentrations several times higher than in other clean soils. In addition to these, there are other sources of pollution associated with rail transport, such as the storage of petroleum products or coal, the resulting waste from the washing of wagons, wheels abrasion, sewage at railway stations and the improper storage of different materials. Maintenance activities of locomotives and wagons represent another source of pollution. Also, near old wooden railways ties, elements as Hg and Cu can be found as a consequence of using antifungal solutions to impregnate the wood [6,8].

In our country, Romanian railways (CFR) were established as an institution in 1880, and the first railway was put into operation in 1854. It connected Oravița and Baziaş, with a length of 62.5 km, and was used for the transport of coal. On November, 1856, after technical improvements were made to the line, it was also opened for passenger transport. In September, 1866, the Romanian Parliament approved the construction of 915 km line from Vârciorova to Roman, which would pass through all the important cities of that time: Pitești, Bucharest, Buzău, Brăila, Galați and Tecuci. The first section: Pitești – Bucharest – Galați – Roman, was opened in 1872. The CFR infrastructure is public and can be found in Annex no. 2 of HG 581/1998 published in MO no. 349 of 10.09.1998 with subsequent amendments [9].

2. EXPERIMENTAL

Site description and sample collection

The Public Garden of Galati is located in the central part of the city, between George Coşbuc Boulevard and Griviţei Street. With a surface of approximately 10 ha is one of the largest green areas in the city and one of the most popular. The history of the garden started in 1840 and has developed over the time.



Location	Depth (cm)	Latitudine (N)	Longitudine (E)
Parck entrance	0	45°27 ′04.3"	28°03 ′05.6 "
	5		
	30		
Puşkin entrance	0	45°27 ′03.8 "	28°03′13.0 "
	5		
	30		
Railway entrance	0	45° 27 ′08.9"	28° 03 ′18.1"
	5		
	30		
Left entrace	0	45° 27′ 20.6"	28° 03′ 08.3"
	5		
	30		
Play ground	0	45° 27′ 03.6"	28 °03′ 11.0"
	5		
	30		

Figure 1. Satellite image (GoogleEarth) and geographic coordinates of the sampling areas

The Public Garden has a variety of shrubs and flowers, beautiful landscaped walkways, benches and children’s playgrounds. At the inauguration 3,500 trees were planted under the care of priest Iorga Ghica, a good friend of the ruler Mihail Sturza. In 1913, the garden was enlarged and two large greenhouses with exotic plants were built. Ten years later, in 1923, a pool with a diameter of 20 m and depth of 1.20 m was built [10,11].

The soil samples were taken in November 2022, from surface (0 cm), 5 and 30 cm in depth, of about 0.6 kg each and prepared for the analysis at the INPOLDE Research Center of “Dunarea de Jos” University of Galati, Faculty of Sciences and Environment. The geographic coordinates and the satellite image of these locations are presented in *Figure 1*. Representative samples were collected from the Public Garden, from the main park entrance, Pușkin entrance, railway entrance and left entrance, and also from a playground. The location was chosen to study how road and railway traffic affects the quality of life of the people who use the area in a recreational purpose. This was taken into account because transport is considered to be one of the main causes of environment contamination with pollutants. The city of Galati has the highest density of railways (km/km^2) in the country. The railway network is much developed that that of the capital of Romania, thanks to the triage of wagons, the largest being Triaj Sud, also known as Barboși, that has 32 lines (according to: Plan de calitate a aerului în municipiul Galați pentru oxid de azot și oxizi de azot (NO_2/ NO_x), 2018 [12]).

Method of analysis

The experimental part of this paper was performed in the European Center of Excellence on Environmental Issues within “Dunarea de Jos” University of Galati, Faculty of Sciences and Environment. The analyses were performed with a portable XRF analyzer, Thermo Scientific XLTj-793 Niton. The sample preparation and technical information about this method were described in detail in other papers [1–3].

The samples were three times analyzed and only the average was taken into account and presented in Tables 1 and 2.

To estimate the toxic potential of element concentrations on the human body, the enrichment factor (EF) presented in equation (1) was calculated.

$$EF=\frac{c_{determined}}{c_{European\ average}} \tag{1}$$

Soil enrichment with different toxic elements can provide information about the impact of human activities on soil quality. In this case, EF was calculated to obtain information on traffic pollution about a single element contribution to the final state of soil pollution, by dividing the determined concentration of the elements by the concentration of the same element determined at the European average level, both of them being expressed in mg kg^{-1}. In this case the European averages proposed by Salminen were considered [13,14].

If EF results are lower than 0, there is no pollution; if EF results are between 0 and 1, the soil is unpolluted to slightly polluted; between 1 and 2 is moderated polluted; between 2 and 3 is moderately to heavily polluted; between 3 and 4 is heavily polluted; between 4 and 5 is heavily polluted to the extreme; if EF is higher than 5, the soil is extremely polluted [14].

3. RESULTS AND DISCUSSION

Using the XRF method, a number of six major elements (K, Ca, Ti, V, Mn and Fe) and eight minor elements (Cr, Ni, Cu, Zn, As, Rb, Sr and Pb) were determined and presented in Tables 1 and 2. The device also detected elements such as: Sb, Cd, Ag, Se, Hg, Co, Sc, but with concentrations below the device limits of detection (nd) for all the locations and depths.

Table 1. Major elements concentration identified in the soil samples

Location	Depth (cm)	Major elements concentration (mg kg^{-1})					
		K	Ca	Ti	V	Mn	Fe
Park entrance	0	17209.17	23892.58	4104.8	nd*	533.78	17288.95
	5	15995.79	22122.06	3949.58	nd	550.9	17310.52
	30	16423.71	22154.34	4284.52	79.6	538.6	17496.09
Puşkin entrance	0	18105.29	23512.9	4105.65	nd	457.27	18353.36
	5	18582.38	24863.96	4230.31	nd	580.08	20035.13
	30	19186.64	26775.55	4284.42	87.69	603.25	21827.46
Railway entrance	0	18866.57	24832.73	4381.21	nd	606.77	20705.98
	5	17169.25	45787.52	3730.81	80.79	509.36	19786.18
	30	16260.73	52075.55	3391.743	nd	512.4	16883.74
Left entrance	0	17375.52	29434.63	4121.47	87.51	515.80	18204.16
	5	18547.58	31616.49	4207.35	95.25	640.63	20664.1
	30	18075.24	31951.8	4109.45	85.64	636.81	20238.13
Playground	0	19541.52	16268.79	4325.42	84.79	554.98	18837.13
	5	19537.53	17761.58	4370.43	96.66	585.46	20094.63
	30	18903.77	15557.18	4582.28	nd	619.08	21429.58

*nd - not determined

Table 2. Minor elements concentration identified in the soil samples

Location	Depth (cm)	Minor elements concentration (mg kg^{-1})							
		Cr	Ni	Cu	Zn	As	Rb	Sr	Pb
Park entrance	0	84.36	58.43	33.61	169.55	nd[3]	61.81	44.06	64.53
	5	81.39	51.24	42.97	216.32	nd	57.77	nd	72.84
	30	69.53	nd	nd	96.09	11.41	66.90	nd	31.09
Puşkin entrance	0	70.36	nd	nd	83.81	10.73	66.21	30.94	22.3
	5	74.29	59.8	35.32	78.97	12.78	72.05	nd	25.99
	30	56.94	60.32	nd	51.59	12.27	75.92	nd	17.09
Railway entrance	0	70.39	57.11	36	55.54	nd	73.40	nd	22.78
	5	72.11	57.02	nd	62.18	10.4	70.12	74.79	16.64
	30	106.97	52.64	40.4	78.43	10.85	59.62	42.82	20.62
Left entrance	0	61.07	45.35	nd	83.40	10.31	64.86	28.93	23.26
	5	75.84	68.64	29.24	93.9	11.36	73.60	43.67	35.07
	30	67.94	73.18	39.46	112.53	nd	67.09	55.12	35.83
Playground	0	96.88	nd	30.23	69.72	15.77	68.32	nd	18.89
	5	90.31	55.47	nd	69.99	11.84	70.09	nd	27.42
	30	78.17	nd	nd	64.02	10.69	78.12	nd	22.21
Maximum		106.97	73.18	42.97	216.32	15.77	78.12	74.79	72.84
Minimum		56.94	45.35	29.24	51.59	10.31	57.77	28.93	16.64
Standard deviation		13.25	7.71	4.86	44.74	1.57	5.84	14.39	16.65
Average value[1]		60	18	13	52	7.03	86.8	130	22.6
Normal values[2]		30	20	20	100	5	-	-	20
Alert threshold [2]		100	75	100	300	15	-	-	50
Intervention threshold [2]		300	150	200	600	25	-	-	100

[1]according to www.gtk.fi/pubb/foregsatlas [13];
[2]Reference values for minor and major elements concentrations in soil 756/03.11.1997 [15];
[3] nd - not determined.

Comparing the obtained results with the reference values from the Romanian legislation it was established that in the soil samples collected from the park main entrance, elements such as Cr, Ni, Cu, Zn, As and Pb exceeded the normal concentrations. In the case of Ni, Cr and Pb the concentration values are depending on depth suggesting an anthropic pollution. For this location, Zn at 5 cm depth was found with the highest concentration recorded in this study. It was 2.16 times higher compared to the normal values (100 mg kg^{-1}). Beside Zn, Pb was also found with a maximum concentration of this study. This is not surprising considering the fact that the traffic on Domnească Street is taking place along the Public Garden of Galați and very close to the main entrance.

For Pușkin entrance elements as Cr, Ni, Cu, As and Pb presented values that exceeded the normal concentrations.

For railway entrance the elements that exceeded the normal values were: Cr, Cu, As, Ni and Pb. In this case is reported the highest concentration of chromium. It is present at 30 cm depth with a concentration of 106.97 mg kg^{-1}, 3.57 times higher than the normal value provided by the law, exceeding the alert threshold for sensitive areas (100 mg kg^{-1}). Inorganic pollutants, including heavy metals, usually come from products transported by rail due to the lack of safety measures during transport. In addition, the track area is treated with herbicide, which limits the production and variety of plant species present in the area. As Cr is contained in herbicides, that is a possible source in this study [16]. In studies carried out on atmospheric particle collected from the vicinity of railways, the most ubiquitous elements were Fe, Cu, Mn and Cr. In this case the concentrations of Fe sound in the samples collected from the railway entrance are comparable to those found in this study, and are presenting the same decreasing trend on depth. This trend, in the case of Fe, is observed only at this sampling point, confirming anthropogenic pollution as the source the same trend was observed in the case of manganese [14].

For the left entrance the elements that presented higher values than the normal concentrations were: Cr, Ni, Cu, Zn, Pb and As which was the only one that presented a possible anthropic pollution. In this case was measured the maximum value for Ni at 30 cm, with a concentration of 73.18 mg kg^{-1}. This may indicate the presence of nickel in the parent material which is also confirmed by the fact that concentrations decrease with depth.

Regarding playground location, despite the fact that the level of pollution is lower than the other locations, there are some elements found over the normal values as: chromium, lead and arsenic, toxic elements even for adults.

Table 3. Enrichment factor for soil samples collected from the Public Garden, Galați

EF	Depth (cm)	Cr	Ni	Cu	Zn	As	Rb	Sr	Pb
Park entrance	0	1.4	3.25	2.59	3.26	-	0.71	0.34	2.86
	5	1.4	2.85	3.31	4.16	-	0.67	-	3.22
	30	1.2	-	-	1.85	1.62	0.77	-	1.38
Pușkin entrance	0	1.2	-	-	1.61	1.53	0.76	0.24	0.99
	5	1.2	3.32	2.72	1.52	1.82	0.83	-	1.15
	30	0.9	3.35	-	0.99	1.75	0.87	-	0.76
Railway entrance	0	1.17	3.17	2.77	1.07	-	0.85	-	1.01
	5	1.20	3.17	-	1.20	1.48	0.81	0.58	0.74
	30	1.78	2.92	3.11	1.51	1.54	0.69	0.33	0.91
Left entrance	0	1.02	2.52	-	1.60	1.47	0.75	0.22	1.03
	5	1.26	3.81	2.25	1.81	1.62	0.85	0.34	1.55
	30	1.13	4.07	3.04	2.16	-	0.77	0.42	1.59
Playground	0	1.61	-	2.33	1.34	2.24	0.79	-	0.84
	5	1.51	3.08	-	1.35	1.68	0.81	-	1.21
	30	1.30	-	-	1.23	1.52	0.90	-	0.98

Based on the average value from www.gtk.fi/pubb/foregsatlas [13], the enrichment factor was calculated using equation 1 and the results presented in Table 3. The EI was calculated for: Cr, Ni, Cu, Zn, As, Rb, Sr and Pb and ranged from 0.22 (for left entrance, Sr) up to 4.16 (for park entrance, Zn). It should be highlighed that the heavily polluted to extreme values of EF are found at the park entrance for Zn (4.16) at 5 cm depth, and at the left entrance Ni (4.07) at 30 cm depth.

4. CONCLUSIONS

The purpose of this work was to analyze several representative soil samples, taken from the Public Garden of Galati, from the principal and secondary entries and from the playground area. The location was chosen to study if traffic affects the quality of the garden's soil which in turn affects the quality of life of the people who use the area recreationally. The area is influenced by both road and rail traffic. The soil samples were about 0.6 kg, collected from surface (0 cm), 5 cm and 30 cm. After the preparation, the soil was analyzed within the European Center of Excellence on Environmental Issues within the "Dunarea de Jos" University of Galati, Faculty of Sciences and Environment, using a portable XRF device, Thermo Scientific XLTj-793, Niton. According to the calculated EF, the highest degree of pollution is present in the samples collected from the main entrance. This is due to the heavy traffic on Domnească Street, and as a consequence most of the pollutants were identified in the first 5 cm of soil. For the secondary entrances, on average, the level of pollution is similar, and the playground area shows, as expected, the lowest level of pollution. The location near by the rail traffic did not show significant excess of heavy metals. The only element present over the limit concentration was Cr, which showed the highest concentration at 30 cm. In rest, high values of Fe and Mn were observed but comparable to those found in other studies. The concentrations of the elements are within normal limits because that area is for human transport and not cargo. The playground location had the lowest amount of heavy metals. This is due to the fact that is protected by vegetation and is located at distance from the main road.

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