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Impact of urban landfill on soil quality. Case study towns: Aiud and Gura-Humorului

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Abstract. The study presents waste disposal problems in inconsistent conditions and their effect on environmental factors. We analyzed in parallel the monitoring results for 6 months, 3 months, of soil quality in the immediate vicinity of two landfills in different locations: Aiud (Alba County) and Gura Humorului (Suceava County). At building the deposits no sealing of the platform ground was done, and also there weren't provided any plans to make drainage systems, sewage collection and water infiltration through the landfill. It is discharged into the soil, thus favoring the infiltration of various pollutants. This paper aims to assess the impact of inadequate storage conditions of domestic wastes. The objective is to determine the concentration of soil heavy metals (Pb^{2+}, Cu^{2+}, Cd^{2+} and Zn^{2+}) so as to evaluate the degree of soil pollution in and around landfill sites in the two localities. After the test results came, we performed tables and graphs and drew conclusions from them, regarding the variation in pollutant, points most strongly influenced by the deposit activity and correlation of monitored parameters.
Key Words: landfill, heavy metal, municipal solide waste, soil sampling.

Rezumat. Studiul prezintă problematica depozitării deşeurilor menajere în condiţii neconforme şi efectul acestora asupra factorilor de mediu. Sunt prezentate şi analizate în paralel rezultatele obţinute în urma monitorizării timp de 6 luni, respectiv 3 luni, a calităţii solului din imediata vecinătate a două depozite de deşeuri din localităţi diferite: Aiud (jud. Alba) şi Gura Humorului (jud. Suceava). La construcţia depozitelor nu s-a realizat impermeabilizarea patului platformei şi nici nu au fost prevăzute sisteme de drenare, colectare şi epurare a apelor infiltrate prin masa de deşeuri, acestea se evacuează în sol, favorizându-se astfel infiltrarea diverşilor poluanţi. Lucrarea are drept scop evaluarea impactului depozitării în condiţii neadecvate a deşeurilor menajere. Obiectivul este acela de a determina concentraţia metalelor grele din sol (Pb^{2+}, Cu^{2+}, Cd^{2+} şi Zn^{2+}) în vederea evaluarii gradului de poluare a solului în interiorul şi în jurul depozitelor de deşeuri din cele două localităţi. În urma rezultatelor analizelor s-au constituit tabele şi grafice care au fost interpretate şi pe baza cărora s-au tras concluzii în ceea ce priveşte variaţia poluanţilor, punctele cele mai puternic influenţate de activitatea desfăşurată în cadrul depozitului şi corelaţia dintre parametrii monitorizaţi.
Cuvinte cheie: depozite de deşeuri, metale grele, deşeuri menajere urbane, probe de sol.

Introduction. Waste is one of the major sources of pollution in recent decades and has become more of a regional and global humanity problem, than a local one and people are still looking for solutions (Abdelatif & Sulaiman 2001). Due to the continued growth in the quantity of wastes and in their toxicity, there are special problems concerning storage, because they constitute a potential danger for both the environment and health (Beccali et al 2001). In Romania storage is the primary option of municipal waste disposal. Of the total waste generated, only 5% of domestic waste is recycled in Romania (this means that each local district must operate a bulky waste landfill, or a large area, hectares (NEPA 2002).

Localization and characterization of studied areas

Aiud Town is located in Alba county and has the geographic coordinates: 46°19' North latitude parallel and 23°43' East longitude meridian, with an elevation of 258 m (Socaciu & Takacs 2002). In the area there are frequently encountered low strength sand-clay rocks. The climate is temperate continental with warm summers and relatively cold winters with low rainfall as a result of the foehn effect that is felt because of the Apuseni Mountains. Multi-annual average temperature is 8.5°C with average maximum of 20°C and minimum of -30^{0}C. Average annual precipitation amounts are relatively small, totaling approx. 500 mm (Socaciu & Takacs 2002).

Gura Humorului is located in Suceava, South Bucovina region, Northern Romania, with geographical coordinates 25°53'21" East longitude and 47°33'14" latitude North, at an altitude of 407 meters (Cocean & Filip 2008). Climate is influenced by hills and plateaus Scandinavo-Baltic, generally cold and wet. This is influenced by cold air masses coming from the North-East in winter, producing more powerful storms and frosts of air coming from the West, bringing heavier rains, with moderate temperatures. The average annual temperature is 6.50^{0}C, far below the country average (11°C). North wind penetrates winter, bringing strong frosts and frost. Rainfall is between 700 and 1000 mm/year, more intense during spring break.

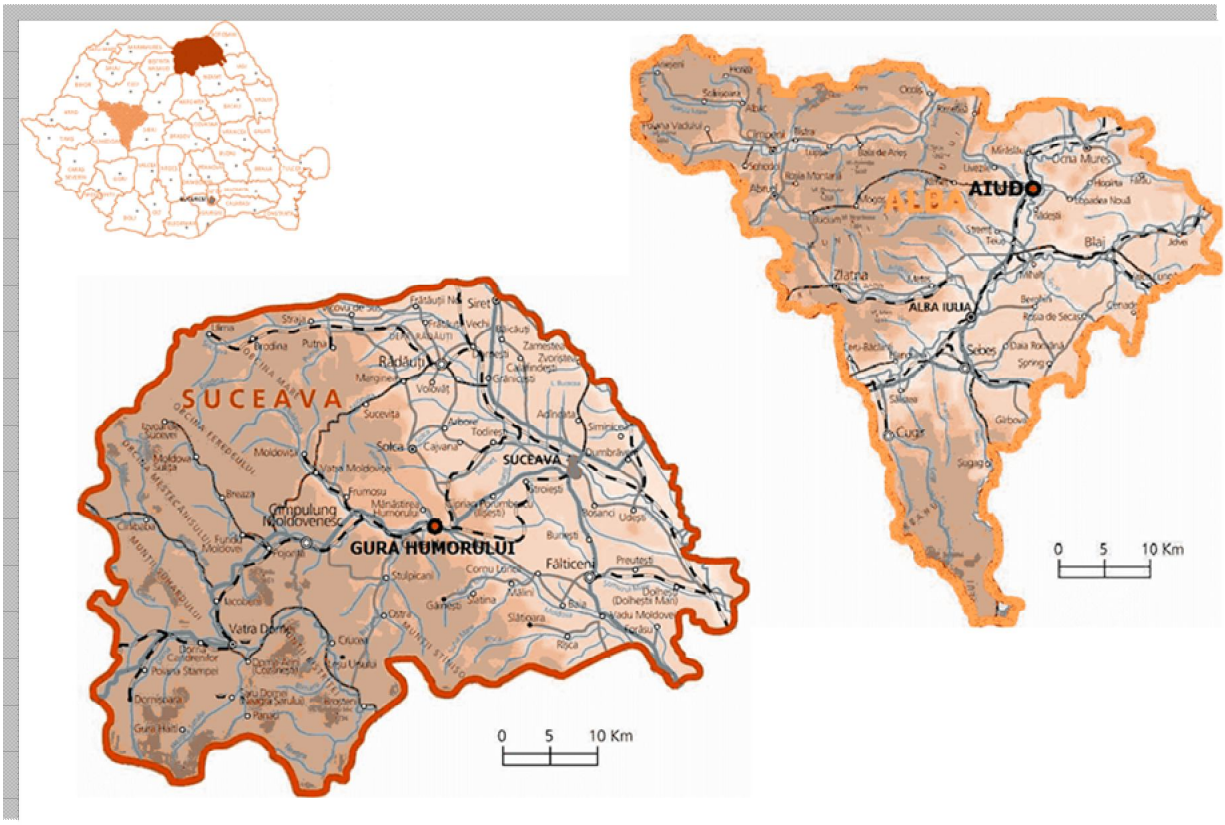


Figure 1. Positioning of two cities: Aiud and Gura Humorului (Source: http:// rotravel. com /Maps-of-Romania, 05/03/2010)

Location of urban landfills. Gura Humorului and Aiud have a similar waste management, characteristic to small towns (Aiud: 25,995 inhabitants, Gura Humorului: 15,656

inhabitants), the quantity and composition of waste deposited, currently being similar. Platforms' operating time is approximately 50 years, reaching a storage area of two hectares.

Platforms are located outside the town, at a distance of about 340 m from inhabited area, which lies near the arable lands, private property. Noteworthy is the fact that they are located close to a stream, the Mureş river, located 500 m from the landfill in Aiud, and the Moldova River, located just 130 m from the landfill in Gura Humorului.

Aiud town landfill is located in the Eastern part of the town. It is bordered to the North with DN1 Alba - Cluj (approx. 165 m), in the North-West with neighborhood of homes Gheorghe Doja (approx. 330 m) and South with railway and the River Mureş (approx. 500 m).

Figure 2 is a satellite picture of the Aiud town, in the center is the landfill, marked in red, and on the right, marked with blue is Mureş River and the DN1 outlined in yellow.

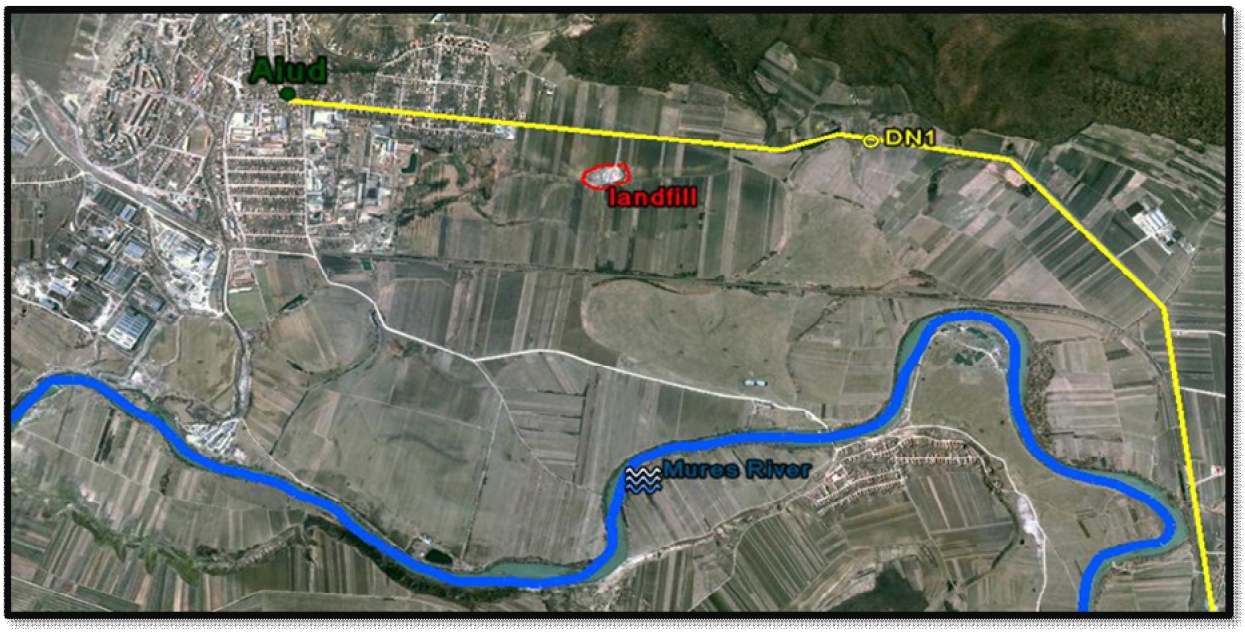


Figure 2. Aiud satellite picture (Source: http://maps.google.com, satellite maps, 05/03/2010)

Figure 3 is a satellite picture of Gura Humorului, located 670 m East of the town. North of the landfill at a distance of 250 m is situated the national road DN17, Suceava – Vatra Dornei (marked with yellow) and in the South, at a distance of 130 m is Moldova River (marked with blue).

Materials and Methods

The materials used in this study are classified in field materials (metal spatula, polyethylene bags) and laboratory materials (sand bath with electric heating, atomic absorption spectrometer, type Varian Spectra AA220).

Sampling. The soil chemical analysis was conducted on soil samples collected near the landfill. The soil was collected after a prior removal of dust, roots, leaves, and other residues that are on the surface. Sample thickness was 5-10 cm, with a metal spatula, and stored in polythene bags, sealed (max. 3 days). In order to monitor the possible pollution of

soil with heavy metals, 6 and 7 sampling points for each location were selected, points of different pollution potential (Paetz & Wilke 2005).

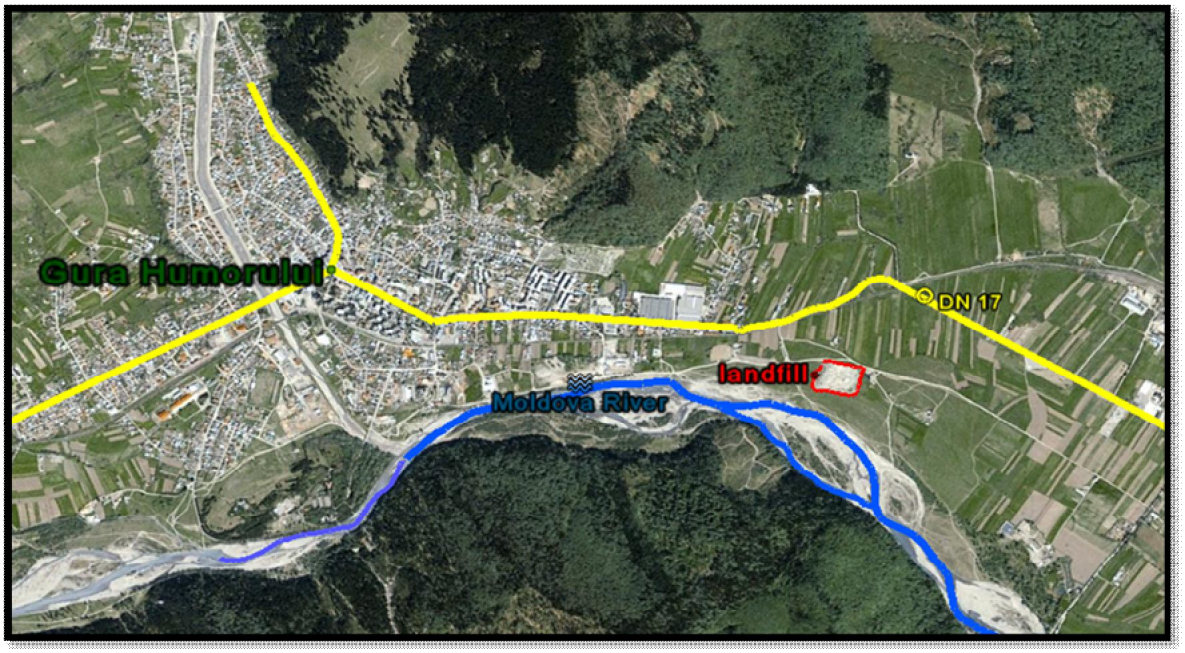


Figure 3. Location of landfill waste (Source: Google Earth Pro May 23, 2010)

Table 1

Location of sampling points

Town	*Sample*	*Description*	*GPS Position*	
Aiud	P1 soil	The North, ramp entrance	46°19′39″ N 23°42′59″ E	247.8 m
	P2 soil	West	46°19′37″ N 23°43′06″ E	248.1 m
	P3 soil	The South-West, towards Mures River	46°19′39″ N 23°43′03″ E	244.7 m
	P4 soil	The South	46°19′40″ N 23°43′01″ E	244.4 m
	P5 soil	The South-East, towards Mures River	46°19′41″ N 23°42′58″ E	244.4 m
	P6 soil	The East	46°19′40″ N 23°42′56″ E	246.9 m
Gura Humorului	P1 soil	The North, inner ramp	47°33'3.23"N, 25°55'7.60"E	458 m
	P2 soil	The West, ramp entrance	47°33'3.01"N 25°55'5.07"E	457 m
	P3 soil	The South	47°32'59.15"N 25°55'3.94"E	457 m
	P4 soil	The South- East – towards Moldova River	47°32'58.82"N, 25°55'7.77"E	457 m
	P5 soil	The South- East – towards Moldova River	47°32'58.24"N, 25°55'11.01"E	457 m
	P6 soil	The South-East	47°32'58.71"N, 25°55'12.52"E	458 m
	Blank	Blank-North at 80 m from the ramp	47°33'6.25"N, 25°55'6.74"E	459 m

Figures 4 and 5 are satellite images of Aiud and Gura Humorului landfills, the sampling points being marked with yellow. The landfill perimeter is marked with red.

Figure 4. Satellite picture of the landfill, Aiud (Source: http://earth.google.com, satellite maps, 5/24/2010)

Figure 5. Satellite picture of the landfill, Gura Humorului (Source: http://earth.google.com, satellite maps, 10/09/2010)

Laboratory Methodology. For the determination of heavy metals (Pb^{2+}, Cu^{2+}, Cd^{2+}, Zn^{2+}) samples were subjected to acid digestion, then quantitative determination was performed by atomic absorption spectrometry (AAS). The devices used to analyze soil samples are: electrically heated sand bath with adjustable power and atomic absorption spectrometer, type Varian Spectra AA220, equipped with air-acetylene flame and graphite furnace, type 110 GTA, fully automated type double beam background correction with deuterium lamp power supply and automatic damper. The reagents used for plotting calibration curves were analytical grade (Wang & Xu 2001). The standard solutions used were Merck-Germany type, concentration 1000 mg/L. The working standard solutions were prepared from stock solutions by dilution with double distilled water. The graphite furnace for determination of calibration solutions were made automatically by the auto-sampler (Jjemba 2005). For determination of Pb^{2+}, Cu^{2+}, Zn^{2+} and Cd^{2+} was used the flame atomic absorption spectrometry with electro-thermal atomization method. The wave-lengths used were: Pb 217.0 nm, Cu 324.8 nm, Cd 228.8 nm, Zn 213.8 nm.

Results and Discussion

The domestic waste landfill impact assessment was based on measurements in the determination of heavy metals (Pb, Cu, Cd, Zn), aiming at highlighting the main changes in the physical-chemical parameters compared with normal values reported in the control elements and also by comparison with existing quality standards set by Romanian legislation.

The following soil samples near the landfill were analyzed: P1, P2, P3, P4, P5 and P6 plus blank monitor PM period October 2009 - June 2010. Aiud landfill was monitored for six months (October 2009 - May 2010), while the one in Gura Humorului for three months (April-June 2010). The results are presented in Table 2.

Analyzing the data table above according to the maximum allowed by law for soil type (clay soil) found in the areas of monitoring, it can be observed that there was a significant overshoot of all parameters analyzed. For clayey soil, the alert threshold concentration of metal ions is: $Pb2^{+}$: 100 mg/kg, Cu^{2+}: 60 mg/kg; Cd^{2+}: 1.5 mg/kg and Zn^{2+}: 200 mg/kg.

Based on the determined values, we composed graphics for each area in order to see the variation of concentration of metal ions according to the monitoring period and depending on the sampling points.

Aiud Area. Based on analytical results (Pb, Cu, Cd, Zn), we can see the numbers are over the standards. We can also see a seasonal variation in the concentration of all parameters analyzed, as in March and December there are the lowest recorded values, and in May the highest values, followed by April and October. This is most visible when Zn^{2+} ion (Figure 6), where the maximum recorded value in May is 568 mg/kg and minimum recorded value in March is 353 mg/kg.

Regarding the concentrations of metal ions in the six sampling points for all months of monitoring, the lowest values observed are in P1, then follows in ascending order the following points: P2, P3, P4, P5, and the highest values are in P6. A different behavior has Cu^{2+} ion, which in October recorded abnormal values in points P5 and P6 (Figure 7).

Gura Humorului Area. The laboratory chemical analysis has shown that in all sampling points the threshold of metals monitored was exceeded. To note is that in the control samples Gura Humorului concentrations of ions of Pb^{2+}, Cu^{2+}, Cd^{2+} and Zn^{2+} are below the threshold value. Following these findings, we can say that the pollution in the activity area is directly influenced by improper storage conditions of domestic waste.

We can also notice a change in values: the highest concentrations recorded were in June and lowest in May. This variation is valid for all metals analyzed, Figure 8 illustrating the values recorded for the Zn^{2+} ion.

Table 2

The test results of soil samples near the two deposits: Aiud and Gura Humorului (GH)

Date	*Sample*	*Metal ion concentration (mg/kg)*							
		Pb^{2+}		Cu^{2+}		Cd^{2+}		Zn^{2+}	
		Aiud	GH	Aiud	GH	Aiud	GH	Aiud	GH
October 2009	P1	176	-	88	-	4	-	498	-
	P2	187		94		4		512	
	P3	199		102		5		528	
	P4	211		110		5		535	
	P5	218		218		6		553	
	P6	223		223		6		561	
November 2009	P1	173	-	86	-	3	-	435	-
	P2	175		86		3		432	
	P3	183		88		4		459	
	P4	188		90		4		465	
	P5	196		97		4		476	
	P6	199		99		4		481	
December 2009	P1	169	-	85	-	3	-	362	-
	P2	173		86		3		360	
	P3	179		88		3		367	
	P4	183		94		4		381	
	P5	192		98		4		400	
	P6	196		100		4		407	
March 2010	P1	166	-	84	-	3	-	353	-
	P2	172		86		3		359	
	P3	177		87		3		366	
	P4	183		93		4		378	
	P5	195		98		4		397	
	P6	203		101		4		411	
April 2010	P1	183	113	92	89	4	2	495	305
	P2	195	127	96	92	4	2	512	342
	P3	209	124	98	91	4	2	524	338
	P4	218	131	104	94	5	3	540	345
	P5	235	139	109	96	5	3	556	362
	P6	237	142	111	97	6	3	561	368
	PM	-	63	-	44	-	1	-	
May 2010	P1	209	103	106	82	5	2	505	295
	P2	227	115	112	86	5	2	542	312
	P3	239	112	115	84	6	2	558	301
	P4	241	128	116	89	6	3	565	330
	P5	239	135	115	92	6	3	562	338
	P6	242	137	116	94	6	3	568	341
	PM	-	59	-	42	-	1	-	143
June 2010	P1		126		94		3		323
	P2		132		96		3		351
	P3		127		94		2		346
	P4		138		97		3		358
	P5		145		99		3		367
	P6		148		101		4		377
	PM		66		47		2		164

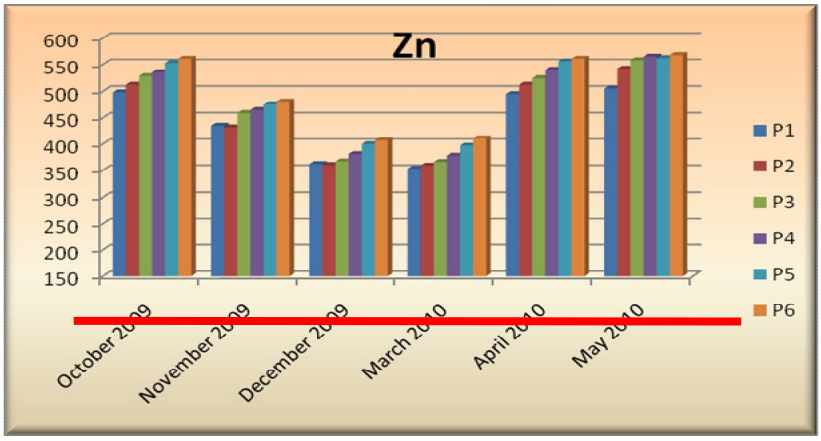


Figure 6. Zn^{2+} concentration depending on the monitoring period, Aiud town.

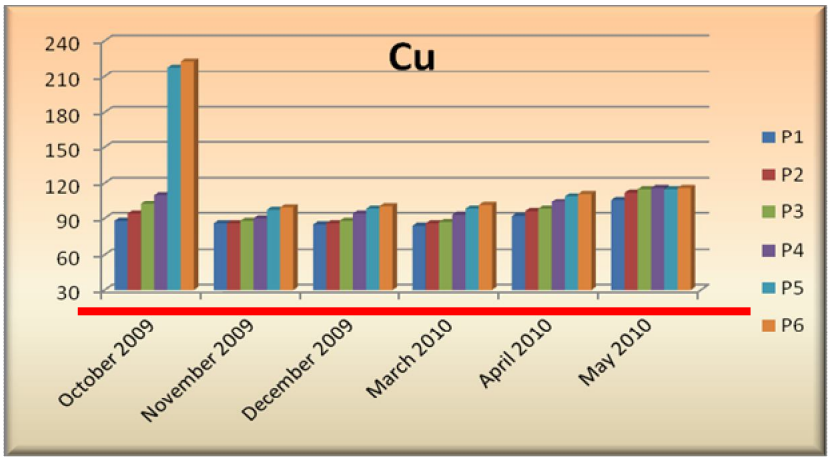


Figure 7. Cu^{2+} concentration according to the monitoring period, Aiud town.

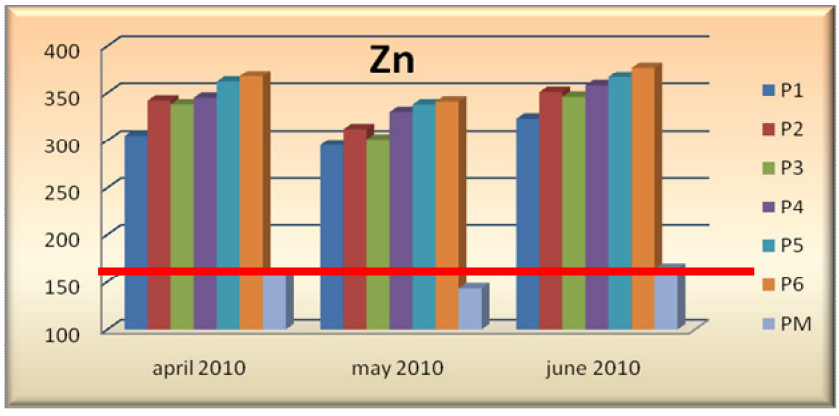
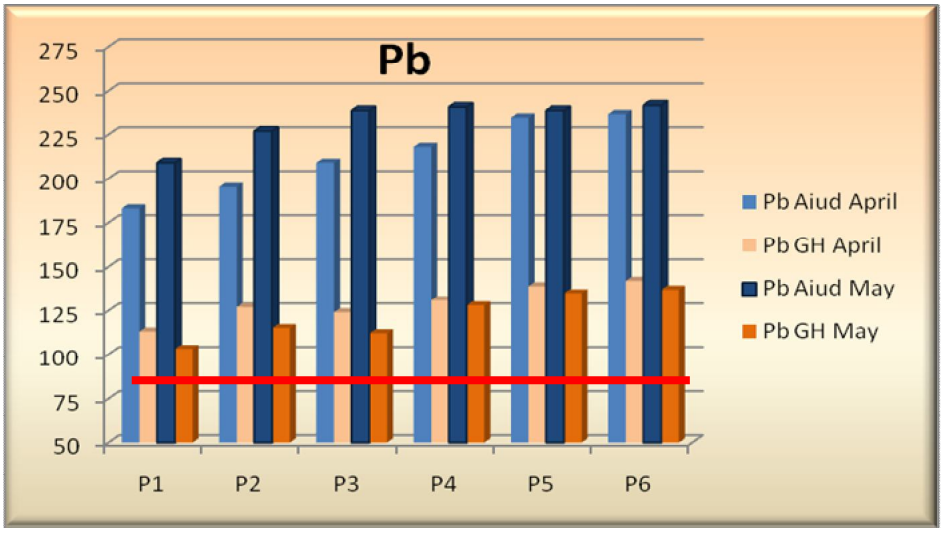


Figure 8. Zn^{2+} concentration depending on the monitoring period, the town of Gura Humorului.

Depending on the sampling, the highest values for all monitored parameters (Pb, Cu, Cd, Zn) are recorded in the P6 point, followed by P5, P4, P2, P3 and P1, the lowest values.

Comparison between the two areas monitored. Analyzing the values recorded in the two surveillance areas, first of all it is noticed a much higher concentration, even double, of metal ions (mainly Pb^{2+} and Cd^{2+}) in the area of Aiud than Gura Humorului.

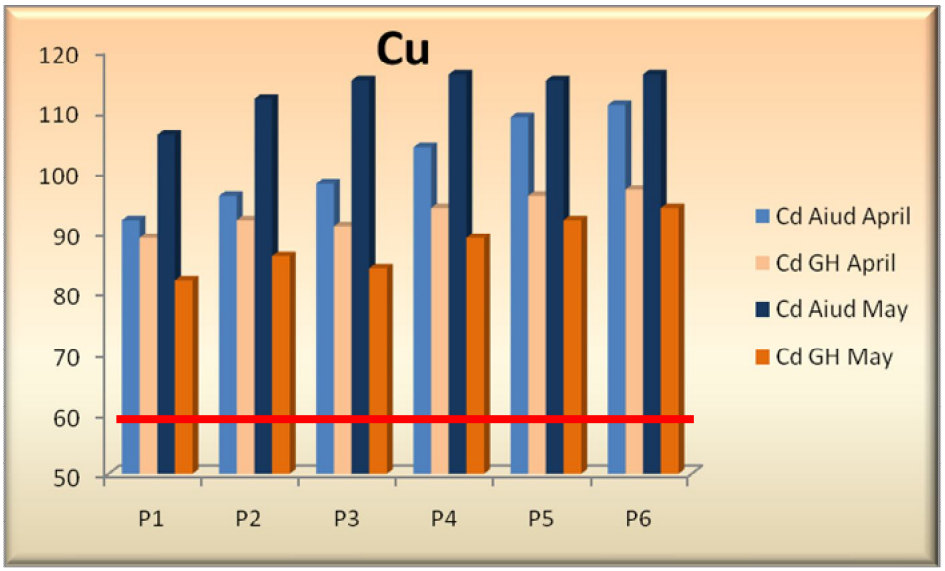
To track the behavior of Pb, Cu, Cd and Zn ions, in the two areas examined there were made the following heavy metal concentrations render graphs, comparative in April and May, in the six sampling points from the two landfills:



Obs: legislation mg/ kg	Clayay soil
Pb^{2+}	100
Cu^{2+}	60
Cd^{2+}	1.5
Zn^{2+}	200

Figure 9. Pb^{2+} concentration at each point, in April and May, at the two landfills.

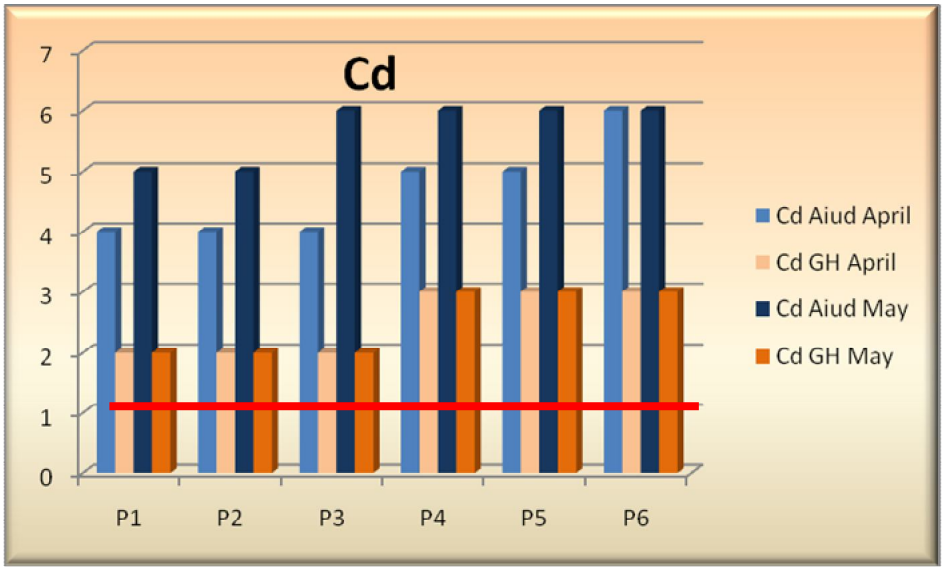
Looking at the first chart we can see that in Aiud were obtained much higher, almost double, values of concentration of lead ions than in Gura Humorului. In May 2010, in Aiud it has been recorded, for P6, the maximum value of the amount of metal ion Pb (242 mg/kg) during the monitoring period. This exceeds the maximum allowed by law, for soil type characteristics for the area, clay soil.



Obs: legislation mg/ kg	Clayay soil
Pb^{2+}	100
Cu^{2+}	60
Cd^{2+}	1.5
Zn^{2+}	200

Figure 10. Cu^{2+} concentration at each point, in April and May, at the two landfills.

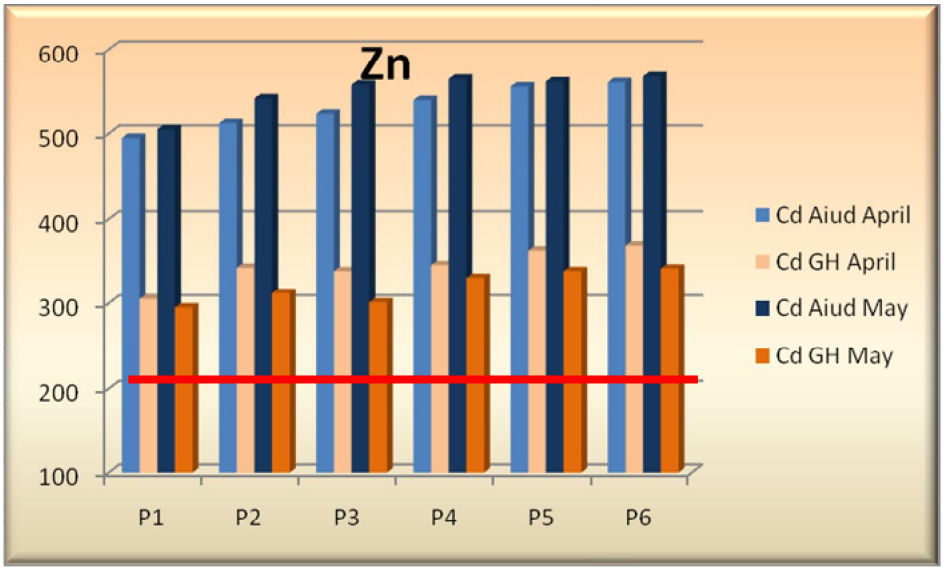
In Aiud the average concentrations of Cu^{2+} is 105 mg/kg and in Gura Humorului is 90 mg/kg. The difference is not significant, but in both cases, values far exceed the maximum allowed by law.



Obs: legislation mg/kg	Clayay soil
Pb^{2+}	100
Cu^{2+}	60
Cd^{2+}	1,5
Zn^{2+}	200

Figure 11. Cd^{2+} concentration at each point, in April and May, at the two landfills.

After analyzing the third graph, we found that in May there were recorded the highest concentrations of Cd (6 mg/kg) in P3, P4, P5 and P6 in Aiud. These values are twice the peak in Gura Humorului, 3 mg/kg. Maximum extent permitted by law is again substantially exceeded.



Obs: legislation mg/kg	Clayay soil
Pb^{2+}	100
Cu^{2+}	60
Cd^{2+}	1,5
Zn^{2+}	200

Figure 12. Zn^{2+} concentration at each point, in April and May, at the two landfills.

In May, in Aiud was reached the highest concentration of Zn^{2+}, 568 mg/kg, much higher than 368 mg/kg, recorded in April, in Gura Humorului. These values are much higher than the maximum allowed, which is 200 mg/kg.

Identifying correlations between observed parameters. To determine the relations between the parameters analyzed, we used the linear regression method, Pearson correlation coefficient (r) showing the relation between variables. Power correlation coefficient values depending on R^2 are presented in the table below:

Table 3

Power correlation coefficient values depending on R^2

R^2 coefficient values	*Correlation significance*
0.00 – 0.19	Very weak
0.20 – 0.39	Weak
0.40 – 0.69	Average
0.70 – 0.89	Strong
0.90 – 1.00	Very strong

Following linear regression analysis of heavy metals concentration in soil values for the two areas monitored, we obtained the values for the correlation coefficient R^2, which are found in Table 4.

We see a strong correlation between the following parameters: Cu-Zn, Pb-Zn and Pb-Cu, and the coefficient of correlation between Cd and the other elements like Pb, Cu and Zn has lower values, reaching only up to 0.39.

Results of samples taken during the six months monitoring in Aiud town, then subjected to the linear regression analysis, show us that in March and April the R^2 coefficient values are almost identical, the monitored parameters having the same type of relation.

Table 4

Pearson correlation coefficient values

	Pb-Cu		*Pb-Cd*		*Pb-Zn*		*Cu-Cd*		*Cu- Zn*		*Cd-Zn*	
	Aiud	GH	Aiud	GH	Aiud	GH	Aiud	GH	Aiud	GH	Aiud	GH
Oct	0.7		0.9		0.97		0.83		0.8		0.94	
Nov	0.92		0.71		0.95		0.46		0.82		0.85	
Dec	0.96		0.74		0.94		0.88		0.97		0.8	
Mar	0.97		0.73		0.99		0.84		0.98		0.75	
Apr	0.97	0.95	0.73	0.8	0.99	0.98	0.84	0.68	0.98	0.97	0.77	0.73
May	0.99	0.93	0.79	0.9	0.99	0.94	0.74	0.75	0.99	0.99	0.74	0.78
Jun		0.96		0.49		0.99		0.39		0.98		0.4

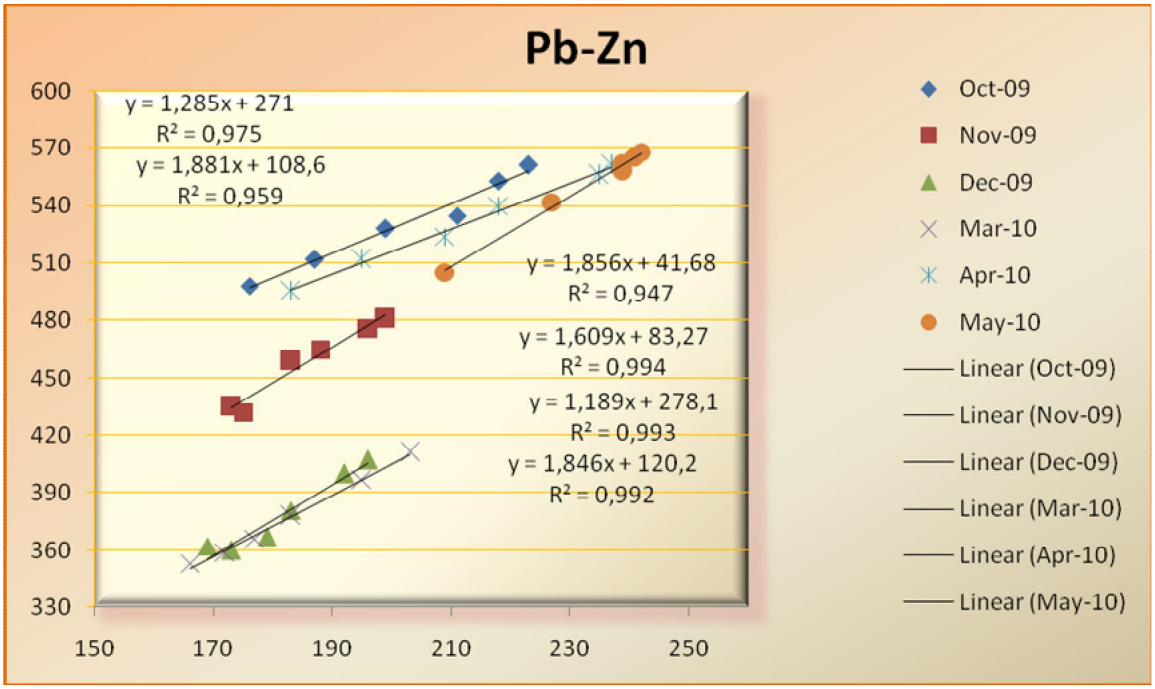


Figure 13. Correlation between Pb^{2+} and Zn^{2+} in the 6 monitoring periods, Aiud town.

We find the strongest dependence between Pb^{2+} and Zn^{2+} in the two areas monitored, with correlation coefficient values exceeding up to 0.94. Figure 12 shows dependencies between these elements in the six months Aiud area monitoring, and Figure 13 shows the area of Gura Humorului for the three months analyzed.

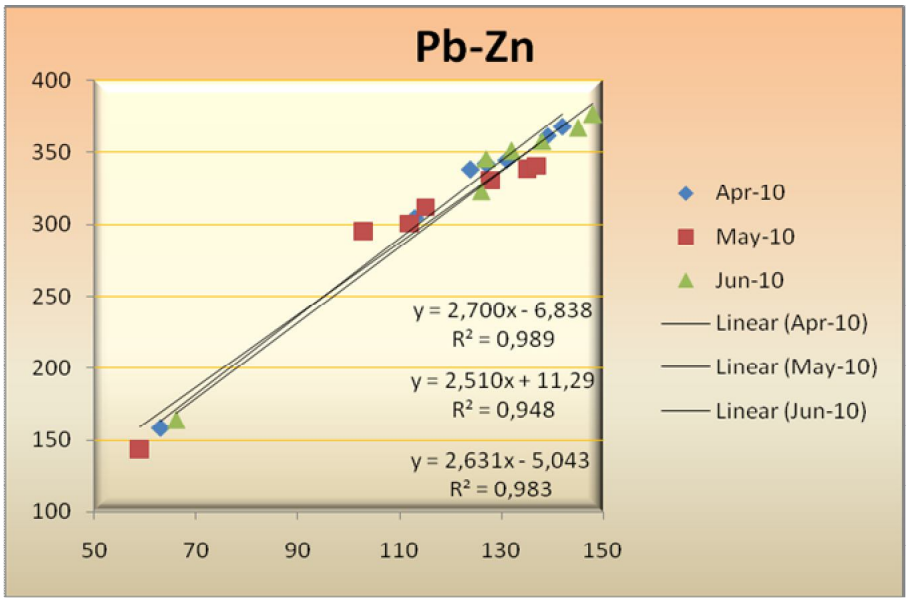


Figure 14. Correlation between Pb^{2+} and Zn^{2+} in the three monitoring periods, Gura Humorului town.

Conclusions. Investigation of effects caused by municipal waste landfill from Gura Humorului town and Aiud town indicate a significant impact on the environment, manifested by soil pollution with heavy metals.

Interpretation of results obtained from chemical analysis laboratory for soil samples shows a concentration exceeded the normal value of lead, copper, cadmium and zinc ions. In all sampling points there is a variation of the recorded values, for example in Aiud the highest concentrations were signaled in May and April and lowest in December and March. Instead, in Gura Humorului, the highest values were recorded in June and lowest in May. The main factor for these differences is the climate in the area, Gura Humorului, being characterized by a cold climate with heavy rainfall.

Depending on the sampling, the highest values for all parameters monitored in the two areas, are recorded in the Western part of the deposit; the following high polluted area is represented by the South and South-West side of the landfill, located near a watercourse. Lowest concentrations are observed in the Northern and Eastern part of the deposit, this variation being influenced by operating mode of the filing at the moment and the inclination of the land.

Comparing the values recorded in the two monitored areas it shows a much higher concentration, even double, of metallic ions in the area of Aiud than in Gura Humorului, these results are influenced by the history of the area of Aiud which was an industrial town since 1894. In Aiud exists since the eighteenth Century a tradition of metalwork and joinery production in the guild. In 1954, becomes its own economic management unit known as "Intreprinderea Metalurgică Aiud" ("Metallurgical Enterprise Aiud") with the repair of rolling stock manufacturing profile throughout the steel sector.

It is also noted a strong correlation between Pb^{2+}, Cu^{2+} and Zn^{2+} ions, characterized by a positive linear regression, the only one that behaves differently in the soil depending on the other parameters is the Cd^{2+} ion.

High concentrations of heavy metals in soil is due to how poor the waste management in the area is, storing together mixed scrap metal, batteries, paper, cardboard, organic fraction (Kaoser et al 2000) all of this bringing a high intake of metal ions in the soil, affecting the soil quality.

Following chemical data interpretation and analysis of landfill situation from Aiud and Gura Humorului, it is shown soil pollution with heavy metals. These sites pose a threat to human health and the environment, and urges the termination of storage activity and start the process of greening the area in compliance with HG349/2005 and Norms of 26/11/2004 - Technical Normative relating to waste disposal, that will be necessary to make works that will be included in the compliance program, to ensure environmental protection of soil, air, taking account of existing deposits and soil characteristics of its location.

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