The current state of municipal solid waste landfills in Suceava county and their impact on water and soil

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ABSTRACT: The location of municipal solid waste (MSW) landfills in inappropriate places is a serious risk to the quality of all environmental factors. These waste disposal sites can become major sources of chemical pollution and biological contamination of soil, groundwater and surface waters due to the high content of heavy metals and organic substances with low biodegradation rate.

The paper discusses in detail the issues of the landfill sites territorial distribution in Suceava County (the Mirăuţi landfill, located in the adjacent area of Suceava city and the Gura Humorului, Radauti, Siret, Campulung Moldovenesc, Fălticeni and Vatra Dornei urban landfills), together with a review of the technical data of the landfills, as well as an evaluation of the qualitative and quantitative effects they produce on the landscape, soil and groundwater quality.

KEY WORDS: chemical pollution, biological contamination, groundwater pollution, alert and intervention thresholds

1. Introduction

Soil pollution is a form of pollution difficult to measure and control. One of the main causes of soil contamination is the uncontrolled disposal of waste resulted from various human activities.

MSW's are represented by the solid residues collected from public housing, usually made of paper, plastic, fabric, ceramic, glass, packaging, batteries, tires, oils and food scraps.

Disposal of this waste is acknowledged as generating impact and risk to the environment and public health (Cojocaru, 1995).

As a result of the evolution and growth of population and civilization, leftovers generated by housekeeping and food preparing, to which we may add a significant amount of materials resulted from food packaging and even some damaged household items, are no longer considered "trash", but a genuine secondary resource of feedstock and recyclable materials (Bularda et al., 1992; Rojanschi and Bran, 2002).

Reducing waste volume and protecting natural resources involve the deployment of selective waste collection, recovery and recycling of reusable waste.

The concept of the waste management options hierarchy, developed in the past 20 years, also included in the European Union Waste Management Strategy, recommends the following order of prioritizing waste management actions: waste prevention - including the minimization of the generated amount, recovery, waste recycling and reuse, energy recovery by incineration and finally disposal.

The main objective of the new Framework Directive, Directive no. 2008/98/EC on waste, consists in the prevention and reduction of negative environmental impacts caused by waste generation and management, as well as reducing overall effects of natural resources utilization and increasing their efficiency.

Nowadays in Romania, waste disposal is the main option for the elimination of municipal waste, and currently there are no municipal waste incineration equipments.

Local municipal administration has the responsibility for MSW management that should imply separate collection, transportation, dismantling, recovery and final disposal of such waste.

The composition of municipal waste is of particular importance, defining the potential for waste recovery and helping establish collection systems.

Analyzing the morphological structure of municipal solid waste in Suceava County, we find that the largest share is represented by biodegradable waste. The biodegradable fraction of MSW (which in Romania is a major component) includes: biodegradable waste produced by households and public food industry, vegetable garden and park waste, biodegradable waste from markets, the biodegradable component of street waste, sludge from municipal wastewater, paper/cardboard waste (of poor quality, that cannot be recycled).

None of the seven MSW disposal sites of the county, classified according to the types of waste contained as non-hazardous locations („b" Class) is in accordance with the provisions of Directive no. 1999/31/EC on waste disposal.

MSW disposal sites may cause serious adverse effects both on environmental factors such as air, water or soil and vegetation, wildlife and people's health over large areas (Rojanschi et al., 2002; Manfredi et al., 2010). The following negative effects may therefore occur:

- unaesthetic landscape changes;
- air pollution with odors, toxic gaseous emissions and particulate pollutants carried by wind;
- groundwater contamination with toxic substances that leach due to soil permeability;
- soil degradation, proportional with increasing of disposed waste layer depth containing organic substances, detergents, pesticides, heavy metals, pathogens, etc., and changes in soil fertility and biocenoses composition in the neighbouring fields;
- permanent physic-chemical and biological contamination of surface waters flowing in the vicinity of the landfills with biodegradable or low biodegradable organic compounds, mineral salts, heavy metals; maximum contamination values are recorded during flood intervals, when waste is washed away by water;
- the presence of diseases carriers such as rodents and some insects.

2. The current situation of MSW landfills. Prospects for the following years

According to the commitments made by Romania in the negotiation process of Chapter 22 - Environment, on the implementation of the Directive for waste disposal, transposed into our legislation by Government Resolution No. 349/2005, transition periods for non-compliant MSW landfills were obtained (for Romania as a whole and for its administrative subdivisions - in our case: Suceava County) (located within the territory according to Fig. 1).

Currently, Suceava County receives technical assistance under the framework of the ISPA Programme no. 2005/RO/16/P/PA/001-04 for the implementation of the project „Integrated management system of municipal waste in Suceava County" (County Waste Management Plan for Suceava).

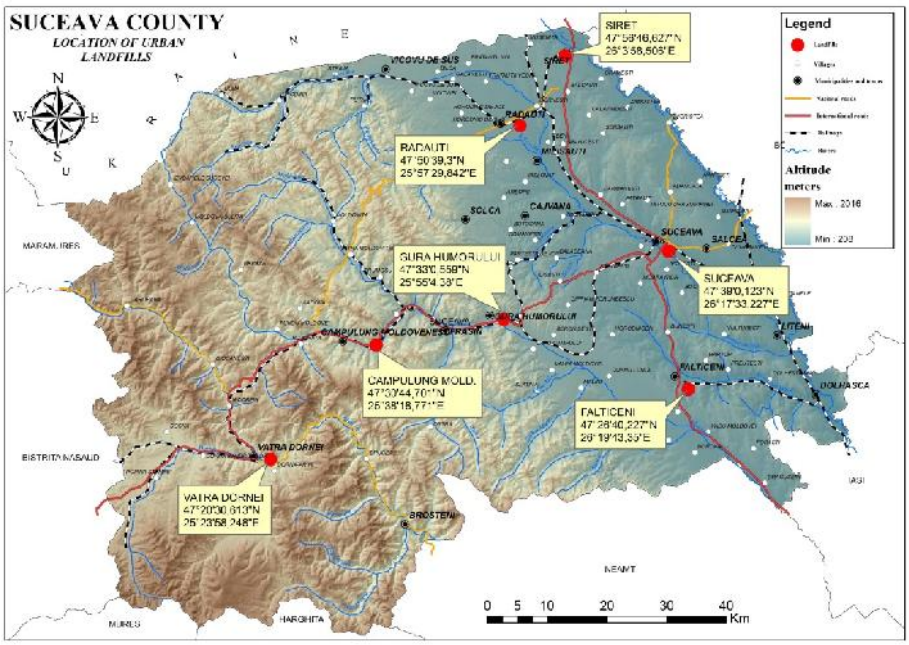

Figure 1. Location of MSW landfills in Suceava County.

According to the environmental agreement no. 9/12.10.2009, revised on 23.03.2010, issued by A.R.P.M. Bacau, the following clauses are proposed:

- closure of 7 non-compliant urban landfills (Suceava, Radauti, Gura Humorului, Falticeni, Campulung Moldovenesc, Siret, Vatra Dornei);
- construction of two compliant landfills (Moara - 5399980m^3 and Pojorata 352500m^3);
- establishment of one waste sorting station at the Moara landfill (6700 tones/yr of paper/cardboard waste, 11220 tones/yr plastic/metal waste); - establishment of five transfer stations: Radauti - 40600 tones/yr; Fălticeni - 27544 tones/yr, Campulung Moldovenesc - 11200 tones/yr, Gura Humorului - 27544 tones/yr (only enlargement in this particular case, because the transfer station was constructed with Phare ESC 2004 funding), Vatra Dornei (only collection center, because the transfer station was constructed with Phare ESC 2004 funding) and of 44,000 individual composting units;

- construction and equipment of waste collection platforms in rural areas with centres for glass and plastic/metal collection;
- construction and equipment of waste collection platforms in urban areas with centres for glass collection, but also for plastic/metal and paper /cardboard collection.

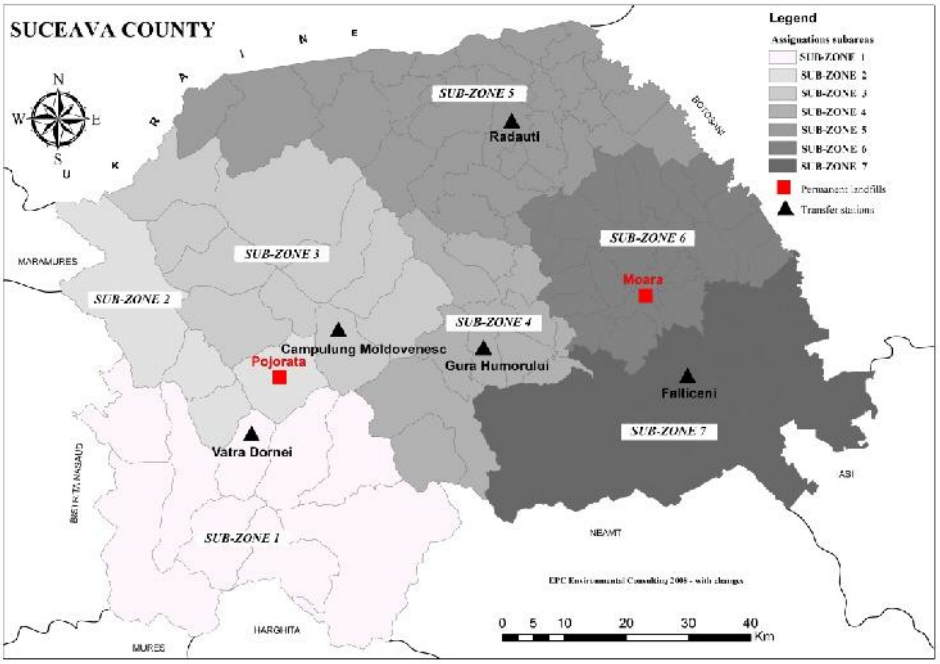

Figure 2. Waste collection sub-zones and future MSW selection and disposal locations in Suceava County.

By means of this project, financed by the EU, the county will be divided into 7 sub zones for waste collection - Figure 2, two waste storage areas (Moara and Pojorâta) will be built and functional by 2014, the transfer stations (Radauti, Fălticeni, Campulung Moldovenesc, Vatra Dornei and Gura Humorului) and a waste sorting station at Moara landfill are or will be constructed / extended.

Until the implementation of the integrated system in Suceava county, the county's municipal waste has been disposed in the existing functional landfills (Fălticeni, Gura Humorului and Campulung Moldovenesc), as well as in the functional landfills of the neighbouring counties (Botosani, Darabani and Targu Neamt).

Currently, dispensations have been obtained for urban waste disposal on the old, non-functional landfills, waste which will be afterwards transferred to the compliant landfills in Moara and Pojorâta, after these become functional in 2014.

3. Data and methods used

The elaboration of the current paper is based on the following information:

- for preparing the maps with the territorial distribution of existing waste disposal sites in Suceava County, the ArcGIS v9.3 software package was used. Raster information was

transformed according to the rectangular coordinate system of the study area, followed by the identification and creation of the vector spatial data system required to draw these maps. As raster support, we used the 2006 ortophotoplans and the satellite images from 2012.

- information on the MSW production (types of produced and collected waste), provided by the sanitation operators and managers of landfills, but based on estimates and not on precise data obtained by weighing;
- the results of physical - chemical analyses for groundwater and soil samples collected from areas bordering municipal landfills;
- calculation of indices for air, water and soil pollution, in order to determine the need for ecological restoration of non-compliant landfills.

4. The territorial distribution of existing waste disposal sites in Suceava County

4.1. The MSW landfill of the Suceava City

The municipal waste storage platform in Suceava is located on public land, belonging to the Ipoteşti local administration, between the right bank of the Suceava River and the Cetatea forest edge, 500 m eastward of the Suceava city. It occupies an area of approximately 11.6 hectares. The landfill's height in some points reaches 8 – 10 m, and in others 2 – 3 m. The Mirauti non-hazardous landfill of the Suceava municipality belongs to class „b", CAEN code 9001, which allows municipal waste disposal up to 200000m^3/yr.

The platform neighbors with the Suceava River in the N, a forested area in the S, with Cetatii Creek and an access road in the E and with another forested area in the W (Fig. 3).

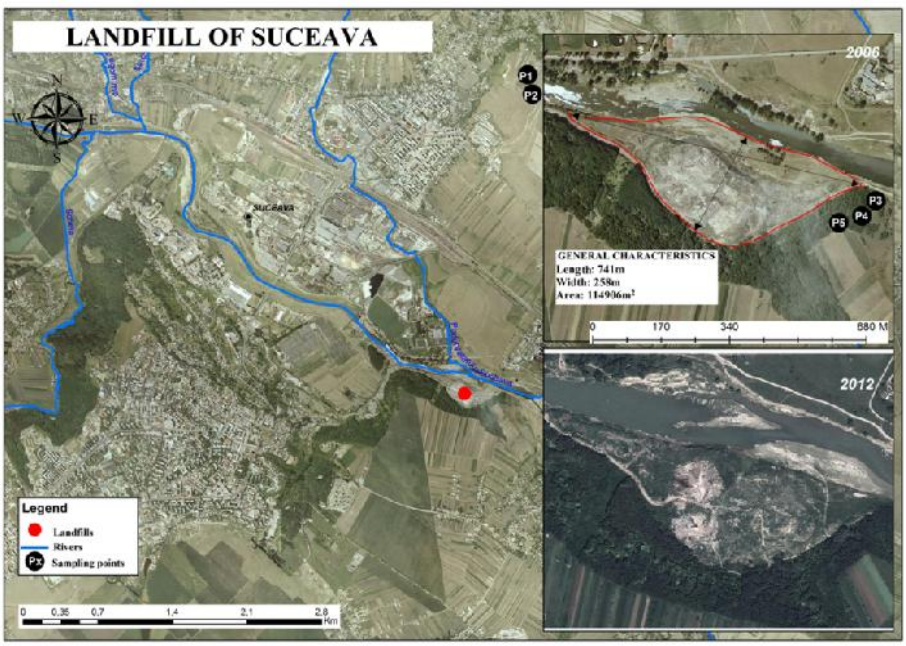

Figure 3. The municipal waste landfill in the Suceava city.

The landfill site is located in the floodplain of the Suceava River - a subunit of the Suceava Plateau, on the right bank of the above mentioned river and at a distance of 200 m from the closest households/human dwellings.

The landfill is incorrectly positioned and moreover, it is not enclosed – Fig. 4. Both municipal and industrial waste have been accepted for disposal. Because of the biogas production, waste self ignites, the fire being difficult to extinguish. At floods, there is the risk that some of the waste reach the Suceava River, due to the degradation of approximately 100 m of the river bank protection structures.

Figure 4. The MSW landfill in Suceava, south-western view (photo by Ditoiu Valeria, 06.2012).

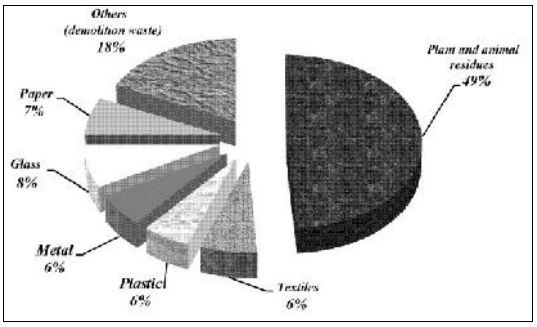

Figure 5. Components of the municipal waste in Suceava (%) – multi-annual statistical data (source: Environmental Protection Agency Suceava).

The Suceava city waste disposal platform was opened in 1972. The platform development followed three periods. Between 1972 and 1982, waste was disposed on a surface of 18000 m^2 (zone 1), with a total amount of 250000 m^3. In the period 1983 - 1993 the area used for waste storage increased to 25000 m^2 (zone 2), with an amount of collected and stored waste of 375000 m^3. During the third period 1994 – 2005, waste was disposed on an area of 72000 m^2 (zone 3), and the amount of disposed waste increased to 1025000 m^3.

From 31.12.2008, waste disposal activities ceased on this platform. The average annual urban waste amount collected in Suceava equals approx. 120000 m^3.

The components of urban waste collected in the Suceava City are: biodegradable - 49%, materials resulting from demolition - 18%, paper - 7%, glass - 8%, metals - 6%, plastic - 5.5% and textiles - 6% - Fig. 5.

4.2. The MSW landfill of Radauti municipality

Radauti town has a mixed landfill of industrial and household waste, constructed in 1983, and located 5km from the urban perimeter, on the County Road Radauti - Satu-Mare – Fig. 1 and 6.

The landfill covers an area of 4.43 ha and has a capacity of 250000t. The total amount of waste to be disposed annually was about 13200t. By the end of 2009, solid waste collected in Radauti was disposed of in a controlled manner, using two methods. A first method consisted in the disposal at the landfill site, located in the eastern part of the town. Since 2010, waste has partly been eliminated by sorting and recycling.

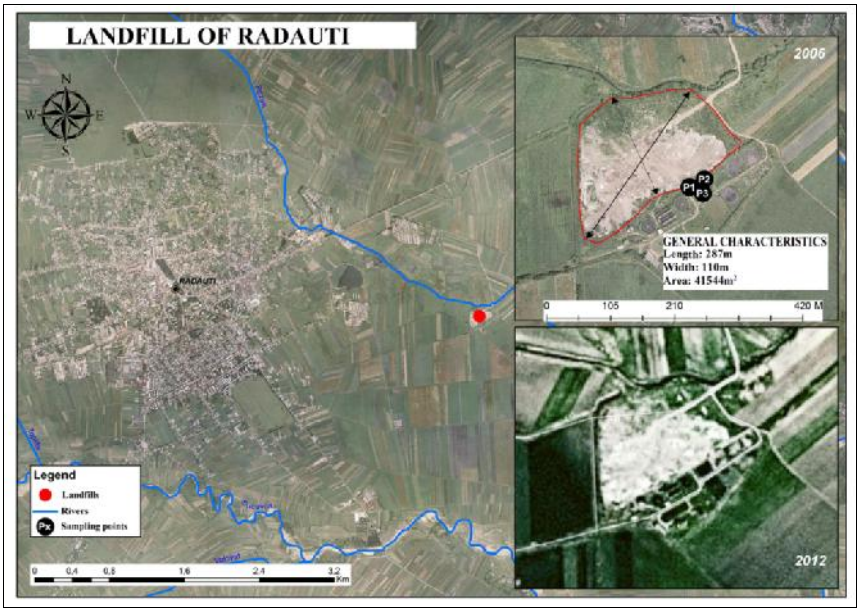

Figure 6. The Radauti municipal landfill location.

4.3. The MSW landfill of Fălticeni municipality

The Waste landfill is located near the city, at a distance of 3.5 km from city center - Fig. 7, with an area of 10000 m^2 (1ha). Each year, over 23,500 tons of waste have been disposed of there. According to the Governmental Resolution No. 349/2005 on waste disposal, the Antileşti - Fălticeni landfill was closed in July 2010, due to reaching of storage capacity.

The landfill perimeter is not properly fenced - Fig. 8d, c, and the platform has no waste collecting and water treatment systems, which causes water to infiltrate into the soil.

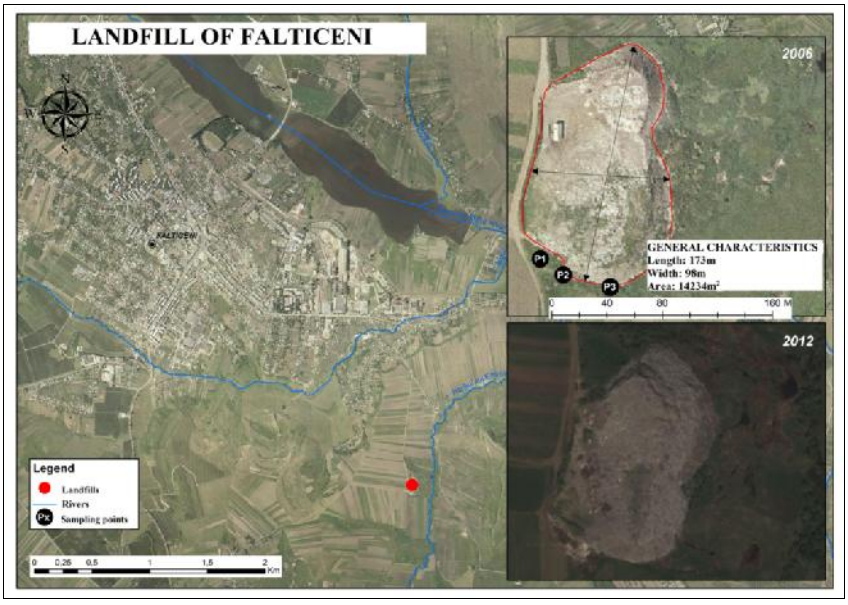

Figure 7. The Fălticeni municipal landfill.

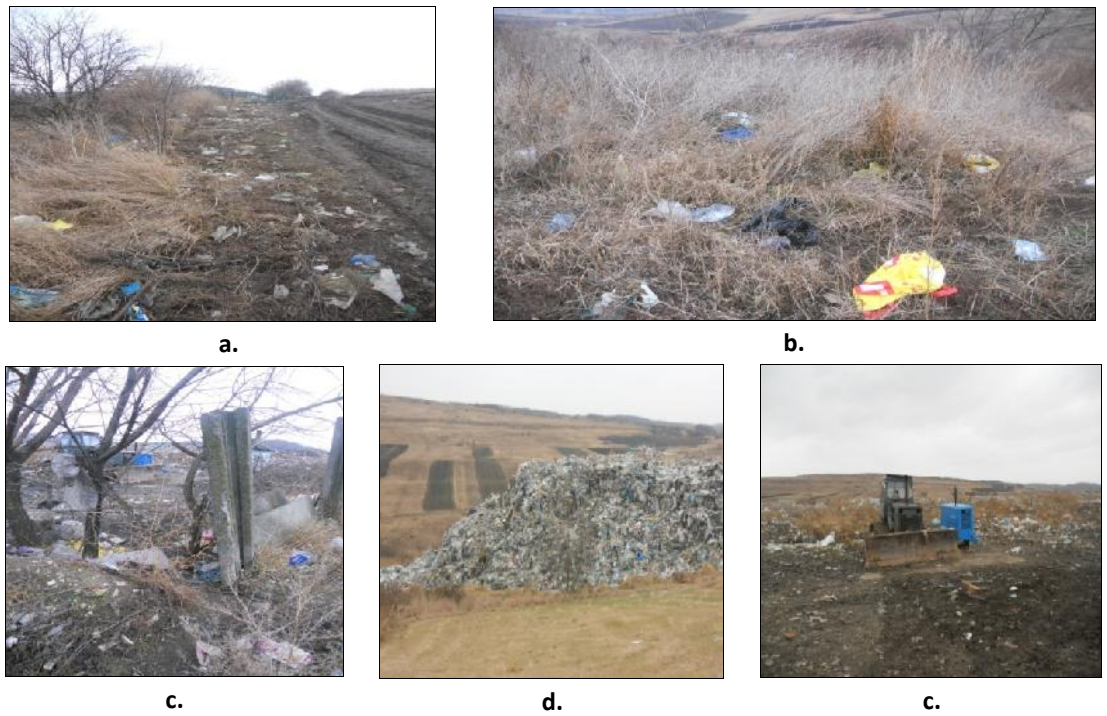

Figure 8. The Antilesti – Falticeni landfill *(photo by Zoita Anisoara, 05. 2011)*

In the landfill platform area, no selective collection technologies have been applied to facilitate ecological reconstruction of the area, reusable materials have not been rendered valuable, and biodegradable materials have not been separated from non-biodegradable materials.

Another hazard is represented by combustible waste (cardboard, plastic, paper, leather, wood, textiles) and moreover, fermentation of organic waste produces biogas that can fuel air polluting combustion. Due to inadequate location of the landfill, household waste is driven away by air currents and scattered on the neighboring fields - Figs 8a and b.

The landfill is improperly surrounded by several concrete plates - Fig. 8c. On the southern side, the slope has a height of 5 meters, it is not stabilized and therefore hazardous, as sliding may occur anytime; on the northern side, the landfill is not enclosed and moreover, has no geophysical stability, which leads to waste sliding and decompaction.

4.4. The Hurghis MSW landfill of the Campulung Moldovenesc municipality

The Hurghiş non-hazardous MSW landfill from Campulung Moldovenesc, Suceava County, is located at approx. 1km eastward of the residential area - Fig. 9 and belongs to the „b" class, with an area of 1.62 ha, and an annual capacity of over 19000t.

The Hurghiş landfill became functional in 1990, with a projected capacity of 115800 m^3, and an area of 2.14 ha.

The Hurghis platform is not made of concrete / asphalt and has almost no fencing - Fig. 9.

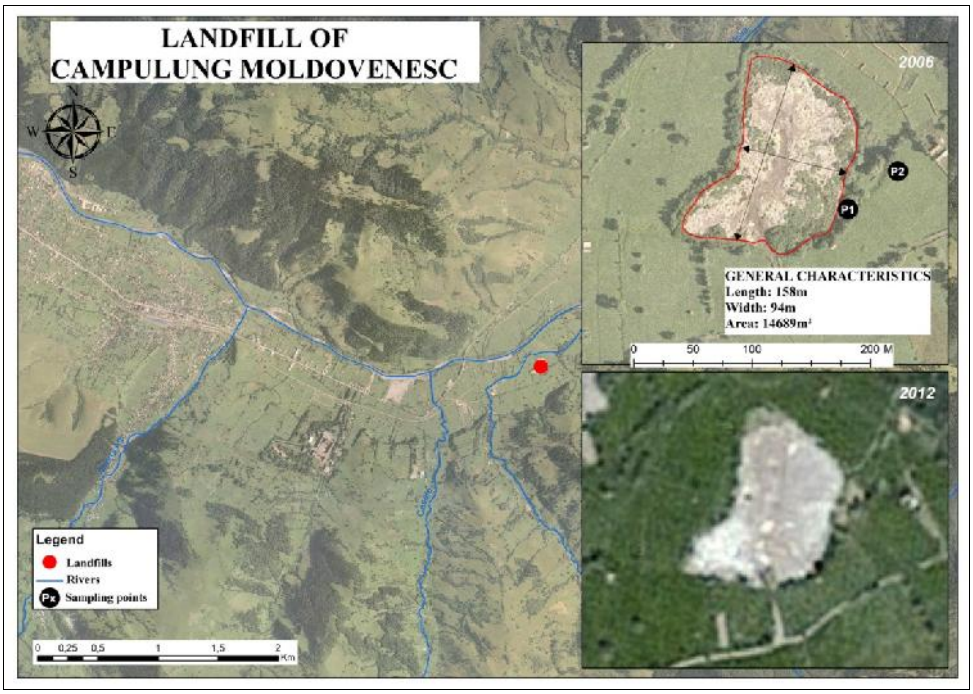

Figure 9. The Hurghis landfill near Campulung Moldovenesc *(photo by Ditoiu Valeria, 06.2011).*

4.5. The urban solid waste landfill of Gura Humorului city

It is a non-hazardous waste landfill belonging to „b" class, with an area of 2,126 ha, located eastward at approx. 800 m distance from the built area - Fig. 10. The location allows the disposal of approx. 16000 m^3/yr, equivalent to 14000t of municipal waste to be disposed of annually.

The landfill is poorly fenced - Figure. 11a, and waste collection is not selective - Fig. 11a and b.

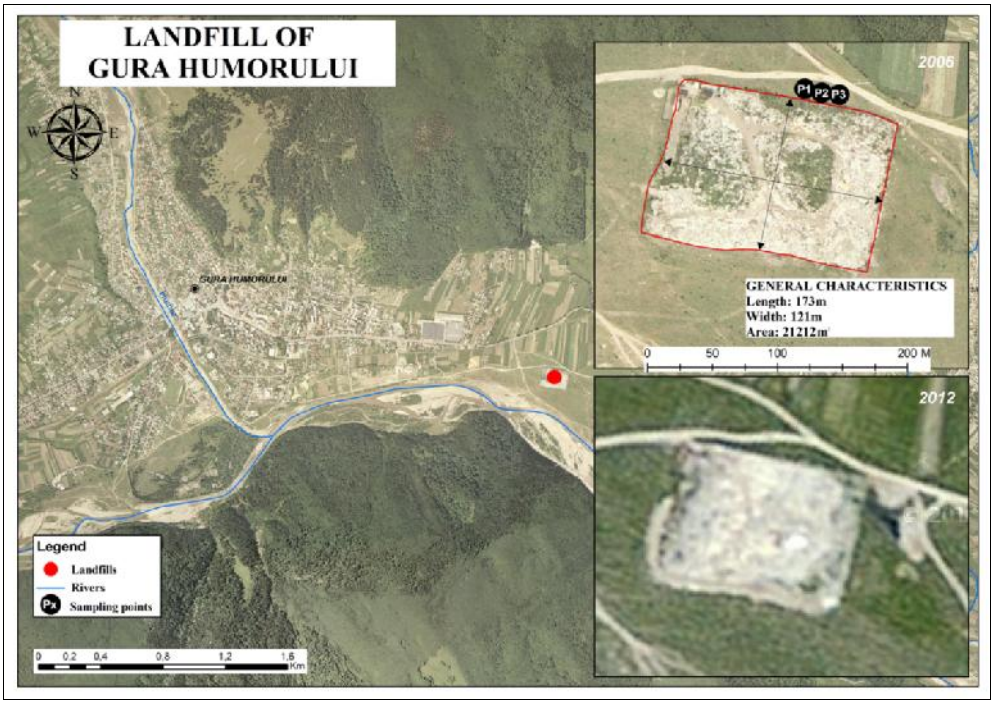

Figure 10. The Gura Humorului municipal landfill.

a. **b.**

Figures 11a, b. The Gura Humorului solid waste landfill (photos by Semeniuc Marius, 05.2011)

4.6. The urban solid waste landfill of Siret town

In 1970, the urban waste landfill became functional, on a plateau area of about 0.8 - 1ha located on the Horait Hill, south-west of the town, at 500 meters distance from the closest households - Fig. 12. This landfill is not properly developed, but placed on unproductive land - Fig. 12. Both household and industrial waste has been disposed here over time.

Since its opening and until its closure in 2008, the management of the landfill was performed by the Siret local administration. With the landfill closure, a post-closure period started, which included the implementation of a monitoring and environmental cleaning program of the area. Currently, the only waste type that has been approved to be disposed of on the landfill is construction waste (rubble, brick fragments etc.). Since this new destination of the landfill was set, about 4700t of waste have been annually disposed on the platform.

The former urban landfill of Siret town is located according to the cadastral map on the parcel 36. The main access road crosses the center of the town, on Suceava Street - a downhill slope road, unpaved, directly connecting the town with both the landfill and the agricultural land in the landfill area - Fig. 12b.

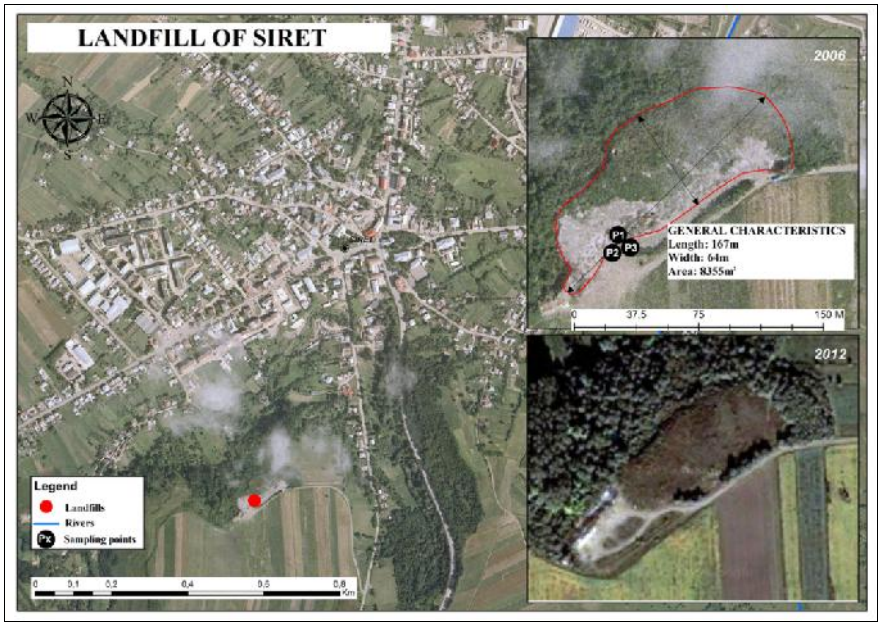

Figure 12a. The urban waste landfill of the Siret town *(photo by Barbuta Razvan, 05.2011)*

Figure 12b. The urban waste landfill of the Siret town *(photo by Barbuta Razvan, 05.2011)*

4.7. The MSW landfill of Vatra Dornei municipality

The municipal waste disposal platform of Vatra Dornei city (Buliceni landfill) is located on public land, belonging to the Vatra Dornei local administration, with an area of 16980 m^2, 500m northward of the built area. Considering a maximum landfill height of 4 m, the maximum platform capacity is 67920 m^3. The platform is located on a hillside area, on the left bank, 50-100

m northward of the Bistrita River floodplain - Fig. 13. The nearest major road is DN 17B Vatra Dornei – Brosteni, which crosses the area 1000 m west of the landfill.

The landfill was opened for use in 1983 and closed in 2005. The distance from residential areas is approximately 1km. The landfill site is not enclosed. Its projected capacity is 80000 m^3, while the utilized capacity equals 60000 m^3.

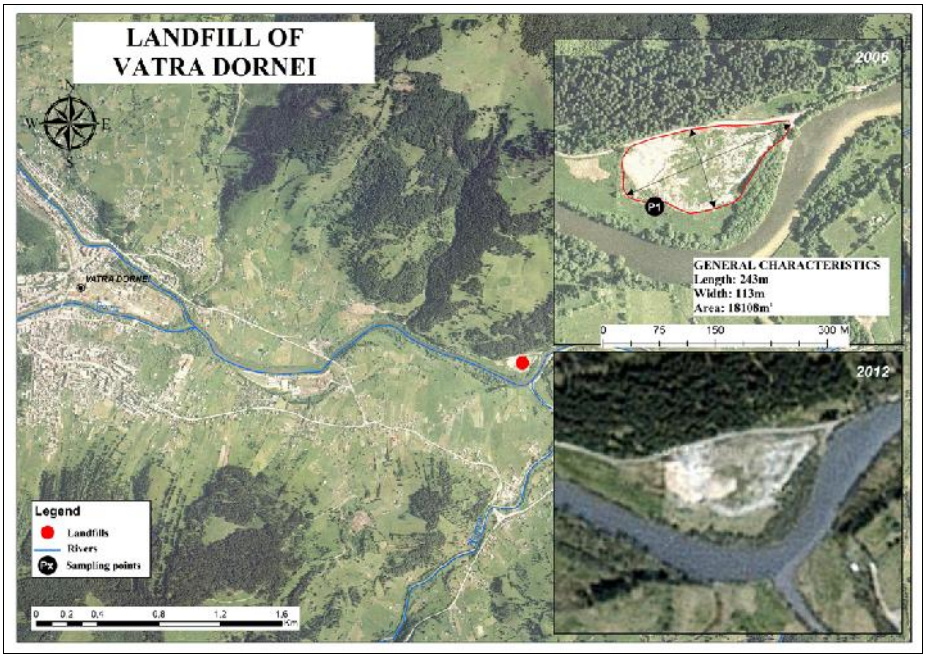

Figure 13. The Vatra Dornei municipal landfill.

The landfill has the following characteristics: lack of platform enclosure (no hedge or prefabricated fence), landfill gas is not collected, no leachate collection system, no monitoring system, no selective waste collection and no recoverable waste collection at the disposal site.

According to their nature, the following shares of different waste categories are estimated and expressed as a percentage: 15% paper and cardboard, 20% plastic, 10% glass, metals 5%, 20% biodegradable waste, construction and demolition waste 15%, textile waste 5%, other 15%.

5. The effects produced by MSW landfills in Suceava County on environmental factors

5.1. Environmental impact assessment by calculation of the pollution index

This index statistically establishes several thresholds (attention, alert, intervention and risk) for each environmental factor, so that pollution prevention and control strategies should be applied for different values of pollution indices (Macoveanu, 2003; Ditoiu Valeria et al., 2005).

The model places pollution indices on a reliability scale. It sets boundaries between different degrees of pollution and establishes general directions of action on the polluted environmental factor, in different situations.

The pollution index (PI) has been calculated for each indicator of environmental factors, according to the formula **[1]:**

$$IP = \frac{MAC - EC}{MAC + EC} \times 100 \quad [1], \text{ where:}$$

- MAC - maximum accepted concentration
- EC - measured or estimated concentration.

According to the pollution index (PI) value, reliability grades can be given for the scale of pollution indices (IP %) presented in Tab. 1

Table 1. Scale of Pollution indices (PI %)

Pollution Index PI (%)	**Reliability Grade**	**Effects of pollutants on environmental factors**
100	10	Pollution level - Excellent (no pollution)
99,99 – 70,01	9	Pollution level - Very good (pollution non-significant for the environment)
70,00	8	Limits for the necessity of quality indices monitoring
69,99 – 15,01	7	Pollution level - Good - (low pollution degree)
15	6	***Attention threshold*** (low pollution, that can produce little disturbance to the environment***)***
14,99 – 0,01	5	Pollution level - Medium (medium pollution, with possible manifestation of pollution phenomenon, dangerous for more sensitive living organisms)
0,00	4	***Alert threshold*** (Pollution that is dangerous for living organisms, which needs the implementation of measures for pollution sources control)
(-0,01) – (-14,99)	3	Pollution level - Bad (badly affected environment, inadequate for most living organisms, which needs activity ceasing measures)
-15,00	2	***Intervention threshold*** (severely affected environment, which needs measures of activity ceasing and ecological reconstruction)
(-15,01) – (-94,99)	1	Pollution level - Very bad (significant pollution with destructive effects on the environment, which requires stopping the polluting source as soon as possible. Urgent decontamination measures for the environmental factors are necessary)
-95		***Danger threshold***
< (-95)	No grades given	Pollution level - Catastrophic, irreversible for the environmental factors (pollution is totally destructive for the environmental factors. Urgent identification measures of the affected area are required, as well as implementation of ecological reconstruction with creation of new ecosystems).

5.1.1. Effects of MSW landfills on soil quality in Suceava, Radauti, Falticeni, Gura Humorului, Campulung Moldovenesc and Siret.

Soil samples were collected from two horizons: 0- 5cm and 5- 30cm, with a sampling corer. For each horizon of each of the sampling points (marked in the Figure 3, 6 , 7, 9 , 10, 12a, 13 with the P symbol and with indices from 1 to 5; example: P1, ..., P5) an average sample was collected and analyzed, which was obtained from four soil samples closely located and mixed for homogenization.

The soil samples were prepared in the laboratory according to the ISO 11464/2006 standard.

a. Determination of pH

pH was determined according to the SR 7184-13/2001 standard protocol: from air-dried soil sample, crushed and sieved through a 2 mm mesh opening, an aqueous suspension was prepared with soil/water concentration of 1/2,5 (mass/volume). The activity of hydrogen ions, expressed

as pH units was measured in this solution. pH measurements were performed with a WTW 526 pH meter, with combined electrode.

b. Determination of metals

Laboratory sample processing for determinations of heavy metals concentration in soil by atomic absorption spectrometry was performed according to the ISO 11466/1999 standard: we used air-dried soil samples, sieved through a sieve with 1.50 mm mesh opening, of which 1 g weighted sub-samples were taken. The sub-samples were digested with aqua regia (2 ml of nitric acid 65% and 6 ml of 37% hydrochloric acid), with the help of a MWS3 Berghof microwave digestion device.

The extracts obtained by filtering the mineralized samples were transferred to 100 ml volumetric flasks, where 0.5 mol/l nitric acid was added for each flask. For the determination of Mn concentration, prior to volume equalization in the volumetric flasks, the extracts were added 10ml of 10% lanthanum chloride solution and then made up to volume with 0.5 mol/l nitric acid.

Measurements of total metals concentrations in the soil (zinc, copper, chromium, cadmium, cobalt, nickel, lead, arsenic) were performed with an AA 220 flame atomic absorption spectrophotometer with graphite furnace, in accordance with the ISO 8288/2001 SR 13315/1996 and SR 8662-2/1997 standards. Sample results are reported to completely dry soil.

Concentrations of measured physical-chemical indicators were compared with the limits imposed by the Order of the Ministry of Waters, Forests and Environmental Protection no. 756/1997, which establishes for soil normal concentration values (NV), alert threshold (AT) and intervention thresholds (IT). The paper considers the alert (AT) and intervention thresholds (IT) for less sensitive land use categories (thus excluding agricultural areas).

Table 2. Locations where average concentration of copper (mg/kg dry soil) indicated varying pollution intensity degrees

Location	Number of samples	Average	PI%	NV= 20	AT = 250	IT = 2000	Reliability Grade	Effects
Suceava (0-5cm)	7	51.15	-43.8	NV = 20	AT = 250	IT = 2000	1	Pollution level - Very bad
Suceava (5-30cm)	4	44.9	-38.4	NV = 20	AT = 250	IT = 2000	1	Pollution level - Very bad
Siret (0-5cm)	4	37.5	-30.4	NV = 20	AT = 250	IT = 2000	1	Pollution level - Very bad
Siret (5-30cm)	4	44.8	-38.2	NV = 20	AT = 250	IT = 2000	1	Pollution level - Very bad
Radauti (0-5cm)	3	84.2	-61.6	NV = 20	AT = 250	IT = 2000	1	Pollution level - Very bad
Radauti (5-30cm)	3	75.1	-57.9	NV = 20	AT = 250	IT = 2000	1	Pollution level - Very bad
Falticeni (0-5cm)	3	71.7	-56.4	NV = 20	AT = 250	IT = 2000	1	Pollution level - Very bad
Falticeni (5-30cm)	3	71.3	-56.2	NV = 20	AT = 250	IT = 2000	1	Pollution level - Very bad
Gura Humorului(0-5cm)	3	33.7	-25.5	NV = 20	AT = 250	IT = 2000	1	Pollution level - Very bad
Gura Humorului(5-30cm)	3	25.7	-12.4	NV = 20	AT = 250	IT = 2000	3	Pollution level - Bad
Campulung Moldovenesc (0-5cm)	2	68.6	-54.8	NV = 20	AT = 250	IT = 2000	1	Pollution level - Very bad
Campulung Moldovenesc (5-30cm)	2	64.2	-53.5	NV = 20	AT = 250	IT = 2000	1	Pollution level - Very bad
Vatra Dornei(0-5cm)	1	27.6	-15.9	NV = 20	AT = 250	IT = 2000	1	Pollution level - Very bad
Vatra Dornei(5-30cm)	1	25.1	-11.3	NV = 20	AT = 250	IT = 2000	3	Pollution level - Bad

Table 3a. Locations where average concentration of zinc (mg/kg dry soil) indicated varying pollution intensity degrees

Location	Number of samples	Average	PI%	NV = 100	AT = 700	IT = 1500	Reliability Grade	Effects
Suceava (0-5cm)	7	160.9	-23.3	NV = 100	AT = 700	IT = 1500	1	Pollution level - Very bad
Suceava (5-30cm)	4	413.3	-61.0	NV = 100	AT = 700	IT = 1500	1	Pollution level - Very bad
Rădăuţi(0-5cm)	3	149.9	-19.9	NV = 100	AT = 700	IT = 1500	1	Pollution level - Very bad
Rădăuţi(5-30cm)	3	269.4	-45.9	NV = 100	AT = 700	IT = 1500	1	Pollution level - Very bad
Câmpulung Moldovenesc(0-5cm)	2	124.1	-10.8	NV = 100	AT = 700	IT = 1500	3	Pollution level - Bad
Câmpulung Moldovenesc (5-30cm)	2	123.6	-10.5	NV = 100	AT = 700	IT = 1500	3	Pollution level - Bad
Vatra Dornei(0-5cm)	1	158.8	-15.9	NV = 100	AT = 700	IT = 1500	1	Pollution level - Very bad
Vatra Dornei(5-30cm)	1	128.9	-12.6	NV = 100	AT = 700	IT = 1500	3	Pollution level - Bad

Table 3b. Instance of significant exceedance of zinc concentration in soil

Suceava Location	Suceava River bank	Suceava River bank	Downstream Suceava MSW landfill	Adjaicent to Suceava MSW landfill	Average	PI%	NV	AT	IT
Date	6.05.2005	24.04.2007	24.04.2007	22.03.2012					
Sampling Depth	5-30cm	5-30cm	5-30cm	5-30cm			100	700	1500
Zn	56.73	90.77	1447	59	413.3	-61.0			

Table 4. Locations where average concentration of chromium (mg/kg dry soil) indicated varying pollution intensity degrees

Location	Number of samples	Average	PI%	NV = 30	AT = 300	IT = 600	Reliability Grade	Effects
Suceava (0-5cm)	7	46.9	-21.9	NV = 30	AT = 300	IT = 600	1	Pollution level - Very bad
Suceava (5-30cm)	4	43.7	-18.5	NV = 30	AT = 300	IT = 600	1	Pollution level - Very bad
Siret (0-5cm)	4	36.6	-9.9	NV = 30	AT = 300	IT = 600	3	Pollution level - Bad
Siret (5-30cm)	4	57.2	-31.2	NV = 30	AT = 300	IT = 600	1	Pollution level - Very bad
Rădăuţi(0-5cm)	3	43.7	-18.6	NV = 30	AT = 300	IT = 600	1	Pollution level - Very bad
Rădăuţi(5-30cm)	3	37.6	-11.2	NV = 30	AT = 300	IT = 600	3	Pollution level - Bad
Fălticeni(0-5cm)	3	28.6	2.4	NV = 30	AT = 300	IT = 600	5	Pollution level - Medium
Fălticeni(5-30cm)	3	34.9	-7.7	NV = 30	AT = 300	IT = 600	3	Pollution level - Bad
Gura Humorului(0-5cm)	3	22.8	13.7	NV = 30	AT = 300	IT = 600	5	Pollution level - Medium
Gura Humorului(5-30cm)	3	26.8	5.7	NV = 30	AT = 300	IT = 600	5	Pollution level - Medium
Câmpulung Moldovenesc(0-5cm)	2	56.8	-30.8	NV = 30	AT = 300	IT = 600	1	Pollution level - Very bad
Câmpulung Moldovenesc (5-30cm)	2	56.7	-30.8	NV = 30	AT = 300	IT = 600	1	Pollution level - Very bad

Table 5a. Locations where average concentration of cadmium (mg/kg dry soil) indicated varying pollution intensity degrees

Location	Number of samples	Average	PI%	NV = 1	AT = 5	IT = 10	Reliability Grade	Effects
Suceava (5-30cm)	4	**0.96**	2.3	NV = 1	AT = 5	IT = 10	5	Pollution level - Medium
Radauti (0-5cm)	3	36.1	-0.02	NV = 1	AT = 5	IT = 10	3	Pollution level - Bad

Table. 5b - Instance of significant exceedance of cadmium concentration in soil

Radauti Location	Adjacent to Radauti MSW landfill	Adjacent to Radauti MSW landfill	Adjaicent to Radauti MSW landfill	Average	PI%	NV = 1	AT = 5	IT = 10
Date	12.05.2006	16.08.2007	20.04..2010					
Depth(cm)	0-5cm	0-5cm	0-5cm	0-5cm	0-5cm			
Cd (mg/kg dry soil)	**107.86**	**0.3**	**0.3**	**36.2**	**-0.02**			
Depth (cm)	5-30cm	5-30cm	5-30cm	5-30cm	5-30cm			
Cd (mg/kg dry soil)	**107.86**	**0.3**	**0.3**	**36.2**	**-0.02**			

Table. 6a Locations where average concentration of cobalt (mg/kg dry soil) indicated varying pollution intensity degrees

Location	Number of samples	Average	PI%	NV = 15	AT = 100	IT = 250	Reliability Grade	Effects
Suceava (0-5cm)	7	12.3	9.5	NV = 15	AT = 100	IT = 250	5	Pollution level - Very bad
Suceava (5-30cm)	4	19.6	-13.2	NV = 15	AT = 100	IT = 250	3	Pollution level - Bad
Siret (5-30cm)	4	11.9	11.5	NV = 15	AT = 100	IT = 250	5	Pollution level - Medium
Radauti (0-5cm)	3	24.3	-23.7	NV = 15	AT = 100	IT = 250	1	Pollution level - Very bad
Radauti (5-30cm)	3	20.2	-14.9	NV = 15	AT = 100	IT = 250	3	Pollution level - Bad
Falticeni (0-5cm)	3	26.2	-27.3	NV = 15	AT = 100	IT = 250	1	Pollution level - Very bad
Falticeni (5-30cm)	3	40.2	-45.6	NV = 15	AT = 100	IT = 250	1	Pollution level - Very bad
Gura Humorului (0-5cm)	3	24.3	-23.6	NV = 15	AT = 100	IT = 250	1	Pollution level - Very bad
Gura Humorului (5-30cm)	3	25.9	-26.7	NV = 15	AT = 100	IT = 250	1	Pollution level - Very bad
Campulung Moldovenesc (0-5cm)	2	14.8	0.8	NV = 15	AT = 100	IT = 250	5	Pollution level - Medium
Campulung Moldovenesc (5-30cm)	2	14.0	3.4	NV = 15	AT = 100	IT = 250	5	Pollution level - Medium
Vatra Dornei (0-5cm)	1	108.9	-75.8	NV = 15	AT = 100	IT = 250	1	Pollution level - Very bad
Vatra Dornei (5-30cm)	1	58.4	-59.1	NV = 15	AT = 100	IT = 250	1	Pollution level - Very bad

Table 6b. Instance of significant exceedance of cobalt concentration in soil

Falticeni location	Adjacent to Falticeni MSW landfill	Adjacent to Falticeni MSW landfill	Adjacent to Falticeni MSW landfill	NV	AT	IT	Average	PI%
Date	03.05.2006	14.08.2007	10.06.2009					
Depth (cm)	5-30cm	5-30cm	5-30cm					
Co (mg/kg dry soil)	11.21	101.51	7.81	15	100	250	40.2	-45.6

Table 6c. Instance of significant exceedance of cobalt concentration in soil

Depth(0-5cm)	Adjacent to Vatra Dornei MSW landfill - 16.05.2006	NV	AT	IT	PI%
Co (mg/kg dry soil)	108.94	15	100	250	-75.8

Table 7a. Locations where average concentration of nickel (mg/kg dry soil) indicated varying pollution intensity degrees

Location	Number of samples	Average	PI%	NV = 20	AT = 200	IT = 500	Reliability Grade	Effects
Suceava (0-5cm)	7	60.1	-50.0	NV = 20	AT = 200	IT = 500	1	Pollution level - Very bad
Suceava (5-30cm)	4	66.8	-53.9	NV = 20	AT = 200	IT = 500	1	Pollution level - Very bad
Siret (0-5cm)	4	27.2	-15.3	NV = 20	AT = 200	IT = 500	1	Pollution level - Very bad
Siret (5-30cm)	4	43.6	-37.1	NV = 20	AT = 200	IT = 500	1	Pollution level - Very bad
Radauti(0-5cm)	3	139.4	-74.9	NV = 20	AT = 200	IT = 500	1	Pollution level - Very bad
Radauti(5-30cm)	3	45.5	-38.9	NV = 20	AT = 200	IT = 500	1	Pollution level - Very bad
Falticeni(0-5cm)	3	48.8	-41.9	NV = 20	AT = 200	IT = 500	1	Pollution level - Very bad
Falticeni(5-30cm)	3	38.3	-31.4	NV = 20	AT = 200	IT = 500	1	Pollution level - Very bad
Gura Humorului(0-5cm)	3	56.9	-47.9	NV = 20	AT = 200	IT = 500	1	Pollution level - Very bad
Gura Humorului(5-30cm)	3	57.7	-48.5	NV = 20	AT = 200	IT = 500	1	Pollution level - Very bad
Campulung Moldovenesc(0-5cm)	2	54.4	-46.2	NV = 20	AT = 200	IT = 500	1	Pollution level - Very bad
Campulung Moldovenesc (5-30cm)	2	62.5	-51.5	NV = 20	AT = 200	IT = 500	1	Pollution level - Very bad
Vatra Dornei(0-5cm)	1	32.5	-23.8	NV = 20	AT = 200	IT = 500	1	Pollution level - Very bad
Vatra Dornei(5-30cm)	1	36.2	-28.9	NV = 20	AT = 200	IT = 500	1	Pollution level - Very bad

Table 7b. Instance of significant exceedance of nickel concentration in soil

Location	Adjacent to Radauti MSW landfill	Adjacent to Radauti MSW landfill	Adjacent to Radauti MSW landfill	NV	AT	IT	Average	PI%
Date	12.05.2006	16.08.2007	20.04..2010					
Depth (cm)	0-5cm	0-5cm	0-5cm					
Ni (mg/kg dry soil)	311.4	64.67	42	20	200	500	139.4	-74.9

Table 8a. Locations where average concentration of lead (mg/kg dry soil) indicated varying pollution intensity degrees

Location	Number of Samples	Average	PI%	NV = 20	AT = 250	IT = 1000	Reliability Grade	Effects
Suceava (0-5cm)	7	40.8	-34.2	NV = 20	AT = 250	IT = 1000	1	Pollution level - Very bad
Suceava (5-30cm)	4	42.7	-36.2	NV = 20	AT = 250	IT = 1000	1	Pollution level - Very bad
Siret (0-5cm)	4	122.9	-72.0	NV = 20	AT = 250	IT = 1000	1	Pollution level - Very bad
Siret (5-30cm)	4	131.6	-73.6	NV = 20	AT = 250	IT = 1000	1	Pollution level - Very bad
Falticeni (0-5cm)	3	43.3	-36.8	NV = 20	AT = 250	IT = 1000	1	Pollution level - Very bad
Falticeni (5-30cm)	3	101.7	-67.1	NV = 20	AT = 250	IT = 1000	1	Pollution level - Very bad
Gura Humorului (0-5cm)	3	27.6	-16.0	NV = 20	AT = 250	IT = 1000	1	Pollution level - Very bad
Gura Humorului (5-30cm)	3	28.7	-17.9	NV = 20	AT = 250	IT = 1000	1	Pollution level - Very bad
Campulung Moldovenesc (0-5cm)	2	29.2	-18.6	NV = 20	AT = 250	IT = 1000	1	Pollution level - Very bad
Campulung Moldovenesc (5-30cm)	2	36.7	-29.5	NV = 20	AT = 250	IT = 1000	1	Pollution level - Very bad
Vatra Dornei (0-5cm)	1	27.5	-15.8	NV = 20	AT = 250	IT = 1000	1	Pollution level - Very bad
Vatra Dornei (5-30cm)	1	37.7	-30.7	NV = 20	AT = 250	IT = 1000	1	Pollution level - Very bad

Table 8b. Instance of significant exceedance of lead concentration in soil

Siret location	12.05.2006	16.08. 2007	03.04.2009	22.03. 2012	Average	PI%	NV	AT	IT
Pb (0-5cm)	18	7.9	210.9	255	122.9	-72.0	20	250	1000
Pb (5-30cm)	15.3	11.6	257.4	242.1	131.6	-73.6	20	250	1000

Table 9. Locations where average concentration of arsenic (mg/kg dry soil) indicated varying pollution intensity degrees

Location	Number of Samples	Average	PI%	NV = 5	AT = 25	IT = 50	Reliability Grade	Effects
Suceava (0-5cm)	7	4.4	6.1	NV = 5	AT = 25	IT = 50	5	Pollution level - Medium
Suceava (5-30cm)	4	6.3	-11.4	NV = 5	AT = 25	IT = 50	3	Pollution level - Bad
Falticeni (0-5cm)	3	7.2	-18.2	NV = 5	AT = 25	IT = 50	1	Pollution level - Very bad
Falticeni (5-30cm)	3	7.3	-18.7	NV = 5	AT = 25	IT = 50	1	Pollution level - Very bad
Gura Humorului (0-5cm)	3	3.9	12.1	NV = 5	AT = 25	IT = 50	5	Pollution level - Medium
Gura Humorului (5-30cm)	3	4.6	4.6	NV = 5	AT = 25	IT = 50	5	Pollution level - Medium
Campulung Moldovenesc (0-5cm)	2	5.7	-6.1	NV = 5	AT = 25	IT = 50	3	Pollution level - Bad
Campulung Moldovenesc (5-30cm)	2	5.6	-5.7	NV = 5	AT = 25	IT = 50	3	Pollution level - Bad
Vatra Dornei (0-5cm)	1	10.6	-35.9	NV = 5	AT = 25	IT = 50	1	Pollution level - Very bad
Vatra Dornei (5-30cm)	1	14.1	-46.7	NV = 5	AT = 25	IT = 50	1	Pollution level - Very bad

Analyzing the results of laboratory measurements in Tab 2 - Tab 9 for different metals and soil horizons, one can observe the following:

for the 0-5 cm horizon:

- „Pollution level - Very bad" - with destructive effects on the environment, which requires implementation of decontamination measures for the landfills:
  • Suceava, because of high values for copper concentration (PI with values of -43.8% - Tab. 2), zinc concentration (PI -23.3% - Tab. 3a), chromium (PI -21.9% - Tab. 4), nickel (PI -50.0% - Tab. 7a) and lead concentration (PI -32.2% - Tab. 8);
  • Gura Humorului due to high values found for copper concentration (PI -25.5% - Tab. 2), cobalt (PI -23.6% - Tab. 6a), nickel (PI - 47.9% - Tab. 7a), and lead concentration (IP -16.0% - Tab. 8);
  • Radauti (PI for copper concentration - 61.6% - Tab. 2; PI for zinc concentration - 19.9% - Tab. 3; PI for chromium -18.6% - Tab. 4; PI for cobalt -23 7% - Tab. 6a; PI for nickel -74.9% - Tab. 7);
  • Campulung Moldovenesc (PI for copper concentration -54.85% - Tab. 2; PI for chromium - 30.8% - Tab. 4; PI for nickel -46.2% - Tab. 7a and PI for lead concentration -18.6% - Tab. 8);
  • Vatra Dornei (PI for copper concentration -15.9% - Tab. 2; PI for zinc -15.9 - Tab. 3a; PI for cobalt -75.79% - Tab. 6a; PI for nickel - 23.8% - Tab. 7a; PI for lead -15.8% - Tab. 8a and PI for arsenic -35.85% - Tab. 9);
- „Pollution level – Bad" for the elements: zinc (PI -10.8% at Campulung Moldovenesc MSW landfill), chromium (PI -9.9% at Siret MSW landfill), cadmium (PI -0.02% at Radauti MSW landfill) and arsenic (PI -6.1% at Campulung Moldovenesc MSW landfill);
- „Pollution level – Medium" for the elements: chromium at Gura Humorului urban solid waste landfill (PI 13.7%), cobalt at Suceava MSW landfill (PI of 9.5%) and Campulung Moldovenesc MSW landfill (PI of 0.8%), and arsenic at Suceava MSW landfill (PI of 6.1%) and Gura Humorului urban solid waste landfill (PI 12.1%).

for the 5 -30cm horizon:

- „Pollution level - Very bad", with destructive effects on the environment, requiring implementation of decontamination measures for the landfills: Suceava (PI for copper - 38.4%, for zinc -61%, for chromium -18,5%, nickel - 53.9% and lead - 36.2%), Siret (PI for copper -38.2%, for chromium -31.2%, nickel - 37.1% and lead - 73.6%), Radauti (PI for copper -57.9%, zinc -45.9% and nickel -38.9%), Falticeni (PI for copper -56.2%, cobalt -45.6%, nickel - 31.4%, lead -67.1% and arsenic -18.7%), Gura Humorului (PI for cobalt -26,7%, nickel -48.5% and lead 17.9%), Campulung Moldovenesc (PI for copper -53.5%, chromium -30.8% , 51.5% for nickel and 29.5% for lead) and Vatra Dornei (PI for nickel - 28.9%, 30.7% for lead and 47.6% for arsenic);

- „ Pollution level – Bad" for the following landfills: Suceava (PI for cobalt - 13.2% and arsenic 11.4%), the Radauti (PI for chromium -11.2% and cobalt -14.9%), Fălticeni (PI for chromium is 7.7%), Gura Humorului (PI for copper is 12.4%), Campulung Moldovenesc (PI for arsenic concentration is 5.7%) and Vatra Dornei (PI for copper concentration is 11.3% and 12.6% for zinc concentration);
- „Pollution level – Medium" for landfills like: Suceava (PI of 2.3% for cadmium concentration), Siret (PI of 11.5% for cobalt), Gura Humorului (PI of 5.7% for chromium and 4.6% for arsenic) and Campulung Moldovenesc (PI of 3.4% for cobalt).

Analyzing the pollution indexes (PI) average values for the soil samples (Table 2-9 in conjunction with Tab. 1) and their consequent averaging, Figures 14a and 14b resulted, which show that the 0-5cm soil horizon is most pronouncedly degraded around Gura Humorului and Radauti urban solid waste landfills (Fig. 14a) and the 5-30cm soil horizon around Campulung Moldovenesc and Suceava landfills (Fig. 14b).

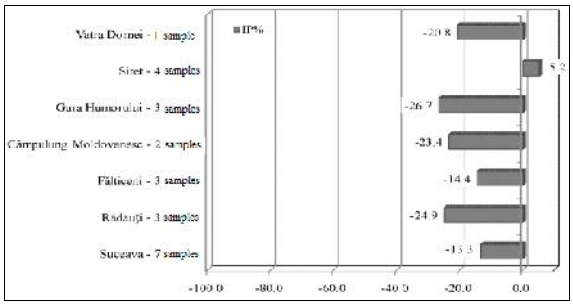

Figure 14a. Average PI% values for the 0-5cm soil horizon

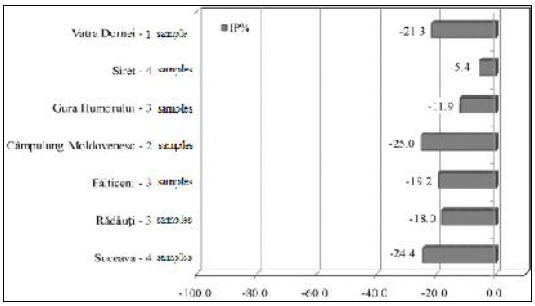

Figure 14b. Average PI% values for the 5-30cm soil horizon

c. Determination of petroleum products in soil was carried out according to the ISO 7877-1/1995 protocol: the soil sample is acidified with sulfuric acid to a pH <5, and extracted with carbon tetrachloride in a Buchi 811 extractor; after evaporation of the solvent, the remaining residue is dissolved in petroleum ether and after solvent evaporation, oil products are determined gravimetrically.

Table 10. Exceedance of petroleum products concentration in the soil

Locqtion Suceava	Suceava River bank	Suceava River bank	Suceava River bank	Downstream Suceava MSW landfill	Downstream Suceava MSW landfill	Downstream Suceava MSW landfill	Adjaicent to Suceava MSW landfill	NV	AT	IT
Date	6.05.2005	25.07.2006	24.04.2007	18.09.2006	24.04.2007	03.04.2009	22.03.2012			
Sampling depth	0-5cm	0-5cm	0-5cm	0-5cm	0-5cm	0-10cm	0-5cm			
Hydrocarbons from oil	*	*	*	*	*	*	2600	< 100	1000	2000
Sampling depth	5-30cm	5-30cm	5-30cm	5-30cm	5-30cm	5-30cm	5-30cm			
Hydrocarbons from oil	*	*	*	*	*	*	3800	< 100	1000	2000

* No sampling or measurements were performed

Analyzing the concentration of petroleum products in the soil (Tab. 10), we found a significant exceedance of the intervention threshold for Suceava MSW landfill, which shows the need for urgent action to remedy the situation.

Except the average statistics used in Tab. 3b, 5b, 6b, 6c, 7b and 8b, several particular situations are given, where analyses revealed exceedance of the AT for some elements in the upper soil horizons (for zinc, at Suceava MSW landfill -Tab. 3b; for cobalt at Fălticeni and Vatra Dornei MSW

landfills -Tab. 6b, 6c; for nickel at Radauti MSW landfill - Tab. 7b and lead at Siret urban landfill - Tab. 8b) or PI (cadmium, the Radauti MSW landfill - Tab. 5b).

5.1.2. Effects of urban solid waste landfills on water quality

Water samples were collected from boreholes located in areas adjacent to landfills. These samples were stored and manipulated for further measurements, according to the SR EN ISO 5667-3/2004 standard.

a. Determination of pH

It was performed according to the SR ISO10523/2009 standard by measuring the activity of hydrogen ions, expressed in pH units, with a WTW 526 pH meter with combined electrode type.

b. Determination of metals

Concentration measurements of dissolved metals in the water were performed by spectrophotometric method with flame atomic absorption, after filtration of samples, as follows: determination of lead, chromium, copper, zinc and cadmium was conducted according to the ISO 8288/2001 standard. The measurements were performed with a flame atomic absorption spectrophotometer and graphite furnace, spectral type AA 220.

c. Determination of organic substances using the CCO-Cr method

Determination of Chemical Oxygen Consumption (CCO-Cr) was performed according to the ISO 6060/1996 standard: in a Kjeldahl digester, water samples were mineralized with potassium dichromate in the presence of silver sulfate mixture - sulfuric acid; the excess of potassium dichromate was titrated with iron and ammonium sulfate in the presence of ferroin.

d. Determination of total phosphorus

Determination of total phosphorus was conducted according to the SR EN ISO 6878/2005 standard, as follows: water samples were treated with a mixture of sulfuric acid - nitric acid; the orthophosphate ions resulted, in the presence of ascorbic acid and ammonium and antimony molybdate form a strong complex of blue color, of which total phosphorus content is measured with a CECIL 8020 spectrophotometer.

e. Determination of ammonia nitrogen (NH4+) was performed according to the STAS 8683-1970 standard: the water sample is buffered at pH – 7.4, in order to inhibit the hydrolysis of organic nitrogen compounds. Ammoniacal nitrogen is distilled in a solution of sulfuric acid, of which in an alkaline environment, in the presence of Nessler reagent, ammoniacal nitrogen is determined photometrically with a CECIL 8020 spectrophotometer.

f. Determination of total nitrogen was carried out according to STAS 7312 protocol: in acid environment in the presence of hydrogen peroxide and iron, nitrogen compounds are reduced to ammonia. Following alkalization, the ammonia released is distilled and absorbed in an acid solution, in which the total nitrogen is determined by treating the sample with Nessler reagent, using a CECIL 8020 spectrophotometer.

The results obtained are summarized for MSW Vatra Dornei, Gura Humorului and Suceava in Tables 11-13.

Table 11. Chemical measurements on water from boreholes in the area adjacent to the Vatra Dornei MSW landfill platform, related pollution indices and effects of pollutants on the environmental factors

Vatra Dornei: 20.12.2005	Borehole P1 VD*	Borehole P2 VD*	Average VD*	Admitted values**	MU (measurement unit)	PI% = 39.96***	Reliability Grade	effects of pollutants on the environmental factors
pH	7.5	7.74	7.62	≥ 6.5 : ≤ 9.5	unit pH			
CCO - Cr	279	131.47	205.24	5	mg O_2/l	**-95.24**	No grade given	Pollution level - Catastrophic
CCO - Mn	156.43	70.73	113.58	-	mg O_2/l			
$H_2S^+S_2^-$	0.01	0.008	0.009	0.1	mg/l	83.49	9	Pollution level – Very good
NH_4^+	40.69	13.6	27.15	0.5	mg/l	**-96.38**	No grade given	Pollution level - Catastrophic
Total nitrogen	62.4	24.1	43.25	-	mg/l			
Total phosphorus	5.06	2.45	3.76	-	mg/l			
Dissolved lead	2.25	1.535	1.89	10	µg/l	68.17	7	Pollution level - Good
Dissolved chromium	1.975	1.855	1.92	50	µg/l	92.62	9	Pollution level – Very good
Dissolved copper	17.855	2.08	9.97	100	µg/l	81.87	9	Pollution level – Very good
Dissolved zinc	244.35	41.75	143.1	5000	µg/l	94.44	9	Pollution level – Very good
Dissolved cadmium	0.285	0.202	0.24	5	µg/l	90.71	9	Pollution level – Very good

* VD – Vatra Dornei; ** admitted values, according to Law. 458/2002 as amended by Law 311/2004, Government Resolution 11 2010; Law 124/2010; GR 1/2011 (on groundwater quality (drinking water) *** Mean PI% value/location/measurements may be graded with 7 and indicates a good pollution level – according to Tab. 1

Table 12. Chemical measurements on water from boreholes in the area adjacent to the Gura Humorului urban landfill, related pollution indices and effects of pollutants on the environmental factors

Gura Humorului 14.12.2005	Borehole P1GH	Borehole P2GH	Borehole P3GH	Average	Admitted values	MU	PI% = 51.59*	Reliability grade	effects of pollutants on the environmental factors
pH	6.89	7.39	7.25	7.18	≥ 6.5 : ≤ 9.5	unit pH		-	-
CCO-Cr	21.14	23.68	21.99	22.27	5	mgO_2/l	**-63.33**	1	Pollution level – Very good
CCO-Mn	9.68	10.09	9.89	9.89	-	mgO_2/l			
$H_2S+S_2^-$	0.003	0.004	0.002	0.00	0.1	mg/l	94.17	9	Pollution level – Very good
NH_4^+	0.461	0.47	0.065	0.33	0.5	mg/l	20.19	7	Pollution level - Good
Total nitrogen	0.358	0.365	1.24	0.65	-	mg/l			
Total phosphorus	0.183	0.217	0.1	0.17	-	mg/l			
Dissolved lead	2.62	3.07	9.14	4.94	10	µg/l	33.84	7	Pollution level - Good
Dissolved chromium	1.08	1.72	0.97	1.26	50	µg/l	95.10	9	Pollution level – Very good
Dissolved copper	88.2	12.31	3.29	34.60	100	µg/l	48.59	7	Pollution level - Good
Dissolved zinc	233.05	42.45	16.6	97.37	5000	µg/l	96.18	9	Pollution level – Very good
Dissolved cadmium	0.282	0.375	0.302	0.32	5	µg/l	87.98	9	Pollution level – Very good

* Mean PI% value/location/determinations may be graded with 7, and indicates a good pollution level - according to Tab. 2.

Table 13. Chemical measurements on water from boreholes in the area adjacent to Suceava MSW landfill platform, related pollution indices and effects of pollutants on the environmental factors

Suceava 6.12.2005	Borehole P1SV	Borehole P3SV	Borehole P5SV	Borehole P7SV	Borehole P9SV	Average	Admitted values	MU	PI% = 8.0*	Reliability grade	effects of pollutants on the environmental factors
pH	7.25	6.89	7.81	7.31	7.25	7.30	≥ 6.5 : ≤ 9.5	unit pH			
CCO-Cr	92.92	155.77	779.73	740.89	111.86	376.23	5	mgO_2/l	**-97.38**	No grade given	Pollution level - Catastrophic
CCO-Mn	40.39	75.88	423.93	453.78	62.92	211.38	-	mgO_2/l			
$H_2S^+S_2^-$	0.004	0.003	0.02	0.008	0.02	0.01	0.1	mg/l	80.18	9	Pollution level – Very good
NH_4^+	1.31	13	55.43	70.67	17.11	31.50	0.5	mg/l	**-96.88**	No grade given	Pollution level - Catastrophic
Total nitrogen	4.88	10.09	63.2	85.8	19.1	36.61	-	mg/l			
Total phosphorus	0.154	0.457	2.25	2.05	0.467	1.08	-	mg/l			
Dissolved lead	4.785	1.835	19.63	18.74	2.99	9.60	10	µg/l	2.06	5	Pollution level - Medium
Dissolved chromium	1.1	9.92	67.8	200	20.61	59.89	50	µg/l	**-9.00**	3	Pollution level - Bad

Suceava 6.12.2005	Borehole P1SV	Borehole P3SV	Borehole P5SV	Borehole P7SV	Borehole P9SV	Average	Admitted values	MU	PI% = 8.0*	Reliability grade	effects of pollutants on the environmental factors
Dissolved copper	34.96	6.08	26.53	129.55	14.60	42.34	100	µg/l	40.51	7	Pollution level - Good
Dissolved zinc	581.5	130.3	296.8	251.7	18.5	255.76	5000	µg/l	90.27	9	Pollution level – Very good
Dissolved cadmium	1.173	0.612	1.537	3.155	0.894	1.47	5	µg/l	54.46	7	Pollution level - Good

Mean PI% value/location/determinations may be graded with 5 and indicate a medium pollution level - according to Tab. 1

Analyzing the data presented in Tab. 11-13, together with the pollution index average values (PI) in Fig. 15 for the groundwater samples, the following can be observed:

- for water samples collected from boreholes adjacent to Suceava landfill, the 8% average PI indicates a „medium pollution level" but for indicators like CCO-Cr and ammoniacal nitrogen, pollution index values below 95% indicate a „danger threshold";
- for water samples collected from boreholes adjacent to Vatra Dornei landfills, with average PI values of 40%, pollution level is „good", but for indicators like CCO-Cr and ammoniacal nitrogen, values of PI lower than -95% indicate a „danger threshold" (due to increased domestic organic matter content);
- for water samples collected from boreholes adjacent to Gura Humorului landfills, the average PI is 51.6%, which indicates a "good pollution level", with the exception of CCO-Cr and ammoniacal nitrogen for which the 63, 3% PI value indicates a „very bad pollution level".

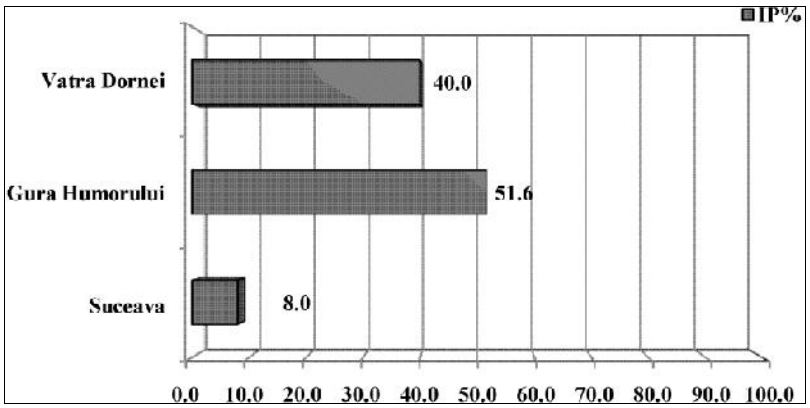

Figure 15. Average PI% values for groundwater under the MSW landfills.

6. Conclusions

Currently, waste management activity in Suceava County is facing a number of problems:

- residential waste collection is not selective, most of it reaching landfills as such, mixed, thus loosing much of its potential usefulness (paper, glass, metals, plastics, textiles etc.);
- existing landfills are often located in sensitive areas (near inhabited areas, surface waters, agricultural land etc.);
- urban waste disposal is performed on bare land;

- most existing urban waste landfills are not operated properly: waste is not compacted and covered periodically with inert materials in order to prevent spread of fire, odors and smoke from waste auto ignition;
- there is no strict control of the quality and quantity of waste entering the landfills;
- many landfills are not fenced and neither do they have proper entering points and warning signs;
- landfills are not properly settled from the viewpoint of environmental protection, leading to pollution of air, water and soil in the neighboring areas;
- there are no facilities for produced biogas recovery;
- the land occupied by landfills has become degraded land that can no longer be used for agricultural purposes;
- pollution indices for most urban landfills in the Suceava County, for some soil and groundwater quality parameters, have „bad" and „very bad" pollution levels, requiring the implementation of ecological restoration measures in those areas.

The problem of waste management in the Suceava county will be resolved by the completion of the project „Integrated management of municipal waste in the Suceava County" by developing the Moara and Pojorata compliant landfills, which will be functional in 2014.

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***_Standard SR 7184-13/2001_ - Soluri. Determinarea pH-ului în suspensii apoase şi saline (masă/volum) şi în pastă la saturaţie, (_SR 7184-13/2001 Standard_ – Soils – Determination of pH in water and saline suspensions (mass/volume) and in saturated paste)

***_Standard SR ISO 11466/_1999 - Calitatea solului. Extracţia microelementelor solubile în apa regală, (_SR ISO 11466/_1999 _Standard_ – Soil Quality. Extraction of soluble trace elements in aqua regia)

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