Journal of Environmental Protection and Ecology 14, No 4, 1608–1613 (2013)

Risk assessment

ESTABLISHING INTERRELATIONS BETWEEN SATURATED AND UNSATURATED ZONE PREMISES FOR STUDYING HAZARDS NEAR MUNICIPAL LANDFILLS. CASE STUDY

B. STANESCU*, GH. BATRINESCU, L. KIM

National Research and Development Institute for Industrial Ecology, 71–73 Drumul Podu Dambovitei Street, 060 652 Bucharest, Romania
E-mail: *evmt@incdecoind.ro*

Abstract. Non-compliant landfills present on intervals of time after the closure period pollutants emissions that affect the environmental quality. It is, therefore, imperative to identify and study the hazards induced by the emissions of the pollutants into the environment, representing an important step in the environmental risk assessment. For a landfill site chosen as a case study, located in Bucharest, were conducted *in situ* and laboratory investigations which consisted of: drilling a number of 6 wells for groundwater quality control, located in downstream, reported to the direction of the groundwater flow; sampling and characterisation of the 24 soil samples from the unsaturated zone and samples of the groundwater from the wells. A small stream that drains the area to the south to the river Dambovita was also qualitatively analysed. The quality indicators analysed were considered representative of the activities carried out in the area of the landfill site, and the results were correlated with lithologic elements identified in location. The results presented in this article led to important conclusions: highlighting the hydraulic connections between surface and underground water, where there are permanent exchanges, the pollutants emitted by the landfill are accumulated mainly on this level.

Keywords: landfills, unsaturated zone, underground water, pollutants.

AIMS AND BACKGROUND

The aim of the research activities was to highlight the existing interrelations between the saturated and the unsaturated zones[1] situated in proximity of the waste landfills, that has effectively stop the activity more than 22 years ago.

The 'Giulesti Sarbi' is a landfill located in the western part of Bucharest, at an average distance of only 10 km from the city center. The landfill makes its presence felt in a negative way, by degradation of the quality of the environmental components, after a considerable period after closing of its activity. Furthermore, facilities for the protection[2,3] of the environmental components do not exists. Therefore, the percolating rainwater on the deposit[4,5], with an appreciable surface estimated at 68 ha, conducts to formation of a leachate[6] taken over by a stream of

[*] For correspondence.

the hydrographic networks tributary of the Dambovita river, located in proximity of the landfill on the southern side[7].

EXPERIMENTAL

Investigations carried out to establish the interrelations between the saturated and the unsaturated zones consisted of:

– manual drillings of 6 wells for the groundwater control, set location in the downstream position of 'Giulesti Sarbi' landfill, on the direction of groundwater flow (this direction is from north to south) by the Dambovita river;

– sampling and geochemichal characterisation of 24 samples of the soil and subsoil (from the unsaturated zone) up to intercept groundwater level;

– sampling and characterisation of the underground water samples from all 6 wells;

– sampling and characterisation of the surface water samples from the natural emissary located near the landfill, which is in the hydraulic connections with groundwater.

Once drilling was made the local lithology and the specific hydraulic characteristics were identified. The lithological characteristics identified were: a topsoil layer with thickness up to 0.30 m, as it is a layer of 0.6 to 1.0 m thickness, consisting of sandy clay, brown-reddish colour and plastic in wet conditions. The behaviour of this layer is semi-permeable. Then comes a layer with a thickness of 0.7 to 0.9 m, consisting of sandy-clay with fine to medium sands with a moderate permeability. In this layer is quartered the ground water. It is of a slightly ascending, the hydrostatic level located at 0.5 to 0.6 m below topographical level.

All the wells were placed in a geometric network (Fig. 1), the two alignments are: SG1–SG3 in the upstream position and SG4–SG6 in the downstream position. Between wells was maintained an equal distance of about 30 m. At the moment of the drillings were collected soil samples from levels: 0–10 cm, 0.5 m, 1.5 m and 2.0 m.

For all samples of the soil/subsoil were analysed the following quality indicators: pH, sulphate, ammonium, the Kjeldahl nitrogen, chloride, nitrate, cadmium, total chromium, copper, nickel, lead and zinc. For the groundwater samples were determined in laboratory quality indicators: pH, BOD, ammonia, nitrites, phenols, substances extractable with organic solvents, total chromium, copper, nickel, lead, zinc, sulphur and hydrogen sulphide.

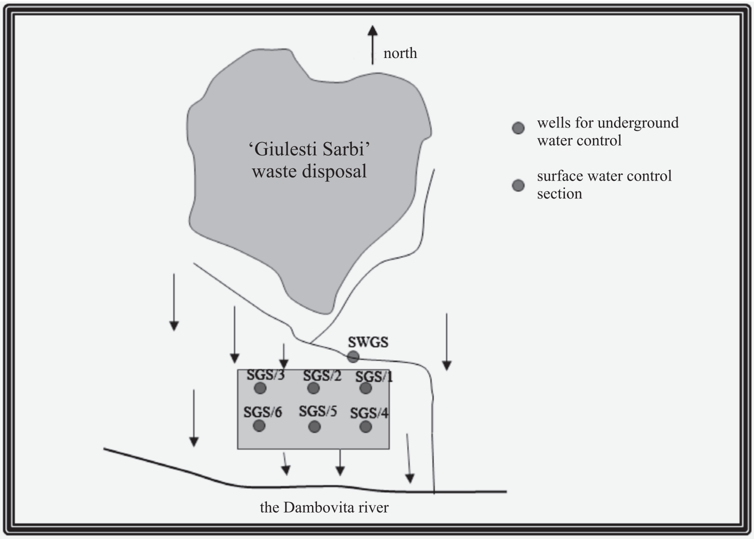

Fig. 1. Location of the sampling points

RESULTS AND DISCUSSION

In the unsaturated zone the pores are filled partly with water and partly with air, allowing phase co-existence at this level in solid, liquid and gas. The liquids arrived, loaded or not with pollutants will go after a vertical component.

The results of the physicochemical determination of the unsaturated zone are presented in Table 1.

Table 1. Results of physicochemical indicators determination

No	Quality indicator	Measure units	SGS 1	SGS 2	SGS 3	SGS 4	SGS 5	SGS 6
1	2	3	4	5	6	7	8	9
		Depth level 0–10 cm						
1	pH	pH units	7.31	7.49	7.14	7.38	7.40	7.3
2	moisture content	%	22.84	26.35	26.1	21.43	22.03	24.21
3	sulphates	mg/kg ds	269.93	139.26	144.06	114.09	109.31	246.47
4	ammonium	mg/kg ds	15.76	12.26	10.01	11.84	14.37	19.45
5	the Kjeldahl nitrogen	% ds	0.45	0.47	0.40	0.43	0.46	0.49
6	chlorides	mg/kg ds	356.7	331.92	419.66	269.34	404.63	96.2
7	nitrate	mg/kg ds	144.17	110.77	143.06	119.71	182.43	150.94
8	cadmium	mg/kg ds	0.28	0.70	0.82	0.42	0.17	0.14
9	total chromium	mg/kg ds	12.06	12.94	12.53	6.00	10.66	10.60
10	copper	mg/kg ds	15.06	14.06	13.77	7.12	9.99	12.75
11	nickel	mg/kg ds	23.29	27.27	28.51	17.74	13.19	11.81
12	lead	mg/kg ds	11.65	7.45	5.37	2.23	3.86	6.04
13	zinc	mg/kg ds	43.84	42.73	33.18	23.47	20.25	36.23

to be continued

Continuation of Table 1

1	2	3	4	5	6	7	8	9
			Depth level 0.5 m					
1	pH	pH units	7.90	7.24	7.43	7.32	7.64	7.61
2	moisture content	%	25.74	24.83	27.57	20.70	20.02	22.22
3	sulphates	mg/kg ds	133.57	153.14	154.46	175.56	278.75	250.20
4	ammonium	mg/kg ds	10.47	9.46	12.31	12.28	12.70	15.36
5	the Kjeldahl nitrogen	% ds	0.41	0.46	0.36	0.40	0.44	0.46
6	chlorides	mg/kg ds	429.07	374.26	395.19	447.15	190.06	494.70
7	nitrate	mg/kg ds	129.41	114.23	133.63	114.01	123.48	116.05
8	cadmium	mg/kg ds	0.14	0.83	0.57	0.14	0.15	0.10
9	total chromium	mg/kg ds	6.65	9.80	13.73	5.52	10.18	10.86
10	copper	mg/kg ds	12.88	11.72	12.72	5.94	4.88	10.26
11	nickel	mg/kg ds	25.76	24.69	27.16	17.95	9.92	7.90
12	lead	mg/kg ds	7.08	6.07	6.00	2.07	2.44	6.85
13	zinc	mg/kg ds	40.05	35.03	42.74	22.23	14.66	25.62
			Depth level 1 m					
1	pH	pH units	7.47	7.66	7.40	7.25	7.76	7.30
2	moisture content	%	17.76	22.1	22.23	21.14	22.70	22.99
3	sulphates	mg/kg ds	141.76	237.75	255.59	347.34	215.05	164.55
4	ammonium	mg/kg ds	16.90	15.06	16.98	11.03	11.14	12.38
5	the Kjeldahl nitrogen	% ds	0.40	0.46	0.34	0.39	0.39	0.41
6	chlorides	mg/kg ds	315.24	377.27	405.78	224.09	445.28	358.00
7	nitrate	mg/kg ds	107.16	126.55	105.50	88.84	106.03	92.02
8	cadmium	mg/kg ds	0.11	0.15	0.37	0.11	0.08	0.03
9	total chromium	mg/kg ds	5.58	11.81	7.69	2.90	10.08	3.40
10	copper	mg/kg ds	4.92	12.67	8.99	2.51	3.01	6.92
11	nickel	mg/kg ds	12.62	2.99	11.29	9.65	7.20	4.31
12	lead	mg/kg ds	5.18	4.99	2.99	0.53	1.18	2.88
13	zinc	mg/kg ds	34.68	35.89	25.95	16.12	14.92	21.28
			Depth level 2 m					
1	pH	pH units	7.27	7.20	7.33	7.52	7.70	7.40
2	moisture content	%	26.81	28.76	27.89	29.69	28.42	28.19
3	sulphates	mg/kg ds	114.56	237.43	163.27	176.06	217.99	168.82
4	ammonium	mg/kg ds	9.19	16.48	12.73	13.08	19.48	12.93
5	the Kjeldahl nitrogen	% ds	0.40	0.43	0.29	0.37	0.43	0.38
6	chlorides	mg/kg ds	177.91	333.43	333.61	276.25	148.72	553.41
7	nitrate	mg/kg ds	119.76	96.50	109.24	89.35	104.73	118.68
8	cadmium	mg/kg ds	0.08	0.09	0.13	0.05	0.05	0.03
9	total chromium	mg/kg ds	2.13	1.63	1.31	2.41	4.60	1.37
10	copper	mg/kg ds	4.25	0.41	1.57	0.27	1.71	2.52
11	nickel	mg/kg ds	1.35	2.59	2.74	5.35	6.17	3.64
12	lead	mg/kg ds	1.98	0.81	0.26	0.13	1.05	1.01
13	zinc	mg/kg ds	22.81	29.94	15.39	13.66	27.58	11.30

ds – dry substance.

The local spatial variations of the values obtained upstream versus downstream, and changes in concentrations of the pollutants in depth from the surface (from the aerated zone) to the saturated zone where groundwater quartered reveal:

– pH-values in the neutral – slightly alkaline domain, the highest value being recorded in SGS1 well (7.90 pH units);

– the moisture content shows the maximum contact with the saturated. The lowest values of the moisture content are found at 1-m depth in upstream wells and 0.5-m depth in downstream;

– the values of the quality indicator ‘sulphate’ show variations both in depth and space upstream-downstream. The higher values are found at levels of 0.5- and 1-m depth in boreholes located downstream, the maximum value is recorded in drilling SG4 (347.39 mg/kg ds);

– variations of values as ‘ammonium’ and ‘the Kjeldahl nitrogen’ reveal higher values in the wells located downstream, but variations are small compared to downstream;

– variations of values of the quality indicator ‘chloride’ reveal that the absolute values increase to downstream, but the distribution of the levels of upstream versus depth shows variations downstream;

– the values of the quality indicator ‘nitrates’ increase from upstream to downstream area in samples coming from the surface. It is found lower values of this indicator as in the saturated zone.

Analysis of the values for ‘heavy metals’ reveals:

– values of ‘cadmium’ decrease in the depth and upstream to downstream;

– values of ‘total chromium’ decrease in downstream section, but with reduced amplitude. The lowest values are found in contact with the saturated zone;

– ‘copper’ values decrease in the unsaturated zone with depth and, in general, to the downstream;

– values of ‘nickel’ decrease in depth in wells located in the upstream section and with a lower amplitude in the downstream section;

– values of ‘lead’ decrease to the saturated zone and upstream to downstream, with a small exception to the 0.5-m depth;

– values of ‘zinc’ show the decrease in the upstream with depth. In the downstream is found that the values recorded at a 2-m depth are similar to those recorded in the upstream section.

The saturated zone is the area where the rock pores are completely filled with water, and water movement in porous medium is imposed by hydraulic load.

The analysis highlights the values obtained to ground water quality control in the vicinity of ‘Giulesti Sarbi’ landfill:

– neutral pH of all samples analysed;

– values of quality indicators ‘ammonium’ and ‘nickel’ in relation to the limit values required by Law 458/2002 (republished on 15.12.2011), induce a significat contribution in pollution of the groundwater quality. It is felt both in upstream wells and those located in the downstream, no appreciable differences with large amplitudes. The results showed that the saturated zone is completed with the surface water quality in the vicinity of the ‘Giulesti Sarbi’ landfill, because the groundwater is in hydraulic connection with the surface water.

For the natural emissary values of quality indicators reveal: ‘bad’ ecological state induced by values of quality indicators ‘nitrate’ and ‘cadmium’, ‘poor’ ecological state values induced by values of quality indicators ‘ammonium’, ‘nitrogen’ and ‘biochemical oxygen demand’; ‘moderate’ ecological state quality induced by values of ‘chlorides’.

CONCLUSIONS

For the saturated zone, the hydraulic connections with natural emissary (stream) from the vicinity are evident, its ecological state is degraded because the pollution induced by the percolating waters of the ‘Giulesti Sarbi’ landfill (its leachate) and the water erosion on its slopes, come directly in this one. At the same time it represents an important source of the groundwater pollution caused by infiltration and hydraulic conections established between surface water and underground water.

Analysis of quality indicators in the unsaturated zone revealed higher values in contact with the saturated zone, upstream and downstream differences, meaning that there were higher values in downstream sections corresponding with the river drainage area Dambovita located south of the site analysed.

The moisture content in the clay layers from the unsaturated zone makes pores, identified in the local lithology, to be occupied by water, fact which elucidates aspects of migration possibilities of the landfill gas in its vicinity, limited by the presence of water in the pores of rocks.

REFERENCES

1. C. W. FETTER: Contaminant Hydrogeology. Department of Geology, University of Wisconsin, Macmillan Publishing Company, New York, 1998, 16–25.
2. C. ZAHARIA, M. SURPATEANU: The Environmental Impact of Municipal Waste Deposition on Water Quality. Environ Eng Manag J, **5** (1), 69 (2006).
3. G. BATRINESCU, E. BIRSAN, G. VASILE, B. STANESCU, E. STANESCU, I. PAUN, M. PETRESCU, C. FILOTE: Identification of the Aquatic Ecosystems Integrating Variables in the Suceava Hydrographic Basin and Their Correlations. J Environ Prot Ecol, **12** (4), 1627 (2011).
4. C. STOICA, I. LUCACIU, Gh. BATRINESCU, B. STANESCU, E. BIRSAN: Evolution of an Aquatic Ecosystem (the Suceava River) for a 3-year Period in Terms of Ecological Dynamics. J Environ Prot Ecol, **13** (1), 61 (2012).
5. V. KYOSEVA, E. TODOROVA, I. DOMBALOV, Y. PELOVSKY: Solid Waste of Sofia Municipality as Raw Material and Energy Resource. J Environ Prot Ecol, **13** (3), 1442 (2012).
6. C. ZAHARIA, M. SURPATEANU, M. MACOVEANU: Evaluation of Environmental Impact Generated by Waste Deposition into a Romanian Urban Landfill. Chem. Bull. (Politehnica University, Timisoara), **50** (64), 1 (2005).
7. Council of the European Communities: Council Directive 1999/31/EC of 26 April 1999 on the Landfill of Waste.

Received 27 June 2013
Revised 30 July 2013