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Research Article

EVALUATION OF LANDFILL POLLUTION WITH SPECIAL EMPHASIS ON HEAVY METALS

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ABSTRACT

Monitoring leachate, groundwater and surface water aiming to determinate the concentration of heavy metals (Hg, Zn, Ni, Cr^{6+},Cd, Pb) at the municipal solid waste landfill Štěpánovice took place in the years 2002–2010. The values of heavy metals concentration oscillated as follows: Zn (0.05 – 0.37 μg/dm^3), Cr^{+6} (0.01 – 3.3 μg/dm^3), Hg (0.0001 – 0.001 (μg/dm^3), Ni (0.001 – 0.19 μg/dm^3, Cd (0.001 – 0.007 μg/dm^3) and Pb (0.002 – 0.176 μg/dm^3). The measured data show that the concentrations of heavy metals met the limits provided by law. Under the current landfill operation mode, the results of measurements do not indicate any negative impact on the quality of surface water, groundwater or leachate water.

Keywords: heavy metals, leachate, surface water, groundwater, landfill, waste.

INTRODUCTION

For a long time, landfilling was the most common waste management option. In many European countries, not to mention the rest of the world, this is still the case [Laner et al. 2012]. In several respects landfilling is the opposite of sustainability. Not only is it a waste of resources but landfills as such constitute a health hazard and an environmental burden [Ettler et al. 2008, Öman and Junestedt 2008, Kalčikova et al. 2011]. Organic waste biodegradation in landfills creates greenhouse gas called landfill gas. Water that enters the landfill forms leachate which can carry pollutants to the surroundings. Environmental problems related to leachate include groundwater pollution and oxygen depletion and ecotoxicity in surface waters [Kjeldsen et al. 2002, Pablos et al. 2011, Modin 2012].

Landfilling and leachate generation

Leachate is the liquid percolated through the waste layers within a landfill cell [Fauziah et al. 2013]. Landfill leachate might contain, among many other constituents, heavy metals in considerable concentrations. The heavy metals may constitute an environmental problem, if the leachate migrates into surface or groundwater, or a treatment issue where the leachate is collected and treated prior to discharge [Baun and Christensen 2004].

The leachate generation is highly dependent on soil types, waste composition, degree of compaction of the waste disposed, amount of landfill received, evapotranspiration and also the type and the age of landfill. Leachate generation begins as soon as the disposal site receives its first batch of waste, where the liquid sourced from the moisture that exists in the waste, water from degradation of putrescible waste and rain. This will continue until the disposal sites cease its operation and no longer receive additional waste. At this instant, leachate will be produced mainly from the degradation of the waste within the waste cells. Due to this factor, characteristics of leachate will vary from time to time. Normally, the concentration will be the highest during the first 3–8 years when biodegradation is occurring very rapidly [Fauziah et al. 2013]. Due to the pollution potential to the surrounding environment, such as local surface water and groundwater, landfill leachate must be treated to meet the local standard for discharge into the receiving water [Kumar and Alappat 2005, Zhang et al. 2013].

Landfilling of waste at sanitary landfills is an important part of the global waste management scheme, and it is crucial to assess the environmental impact of this. In this paper, leachate from Štěpánovice landfill has been size charge fractionated in field and selected metals analysed. The results acquired enable a better understanding of the bioavailability and biological impact of metals discharged via landfill leachate.

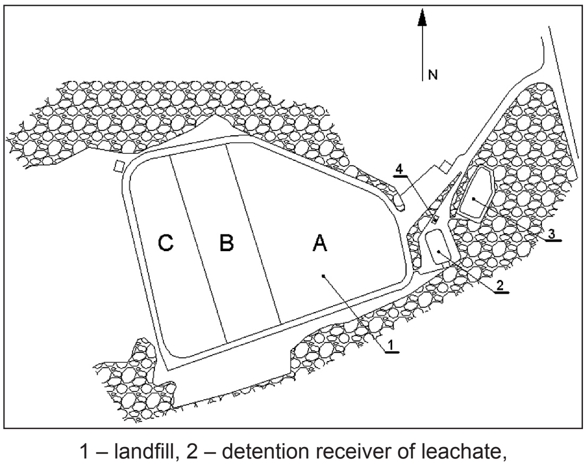
In this paper we describe investigations of the fate of heavy metals for leachate from Štěpánovice landfill and surrounding waters.

MATERIAL AND METHODS

The landfill site

Leachate used in this study was collected from municipal solid waste landfill (MSW) located in Czech Republic, 1 km north of Štěpánovice commune and 1 km south of Dehtín commune. It has been operating since summer 1996 (GPS coordinates of the landfill – 49°26'15.934"N, 13°16'55.352"E). The landfill receives waste from Klatovy with satellite towns and villages for a total of about 37 725 inhabitants, producing in all approx. 20 000 Mg/year of waste to be Landfilled annually. The climate is typically inland, with annual rainfall of 580 mm year^{-1}.

The landfill (Figure 1) is formed by three sub-landfills: landfill A (closed in 2003, area 8750 m²); landfill B (working from 2003, area 26 000 m²); landfill C (that will work after closing part B).



1 – landfill, 2 – detention receiver of leachate,
3 – rainwater reservoir, 4 – entrance gate

Figure 1. Map of three sub-landfills [Kotovicová et al., 2011]

The total volume of both (A, B) parts of the landfill is 289 000 m³. Planned service life of the facility is up to year 2018.

The activities carried out in this landfill are: landfilling of municipal waste, biogas measurement and monitoring, leachate management. In the landfill, there are deposited municipal waste apart from fluid waste, faecal matter, hazardous substances, radioactive and toxic waste. In 1996–2011 approximately 25% of disposed waste was of organic origin. The rest was glass, paper, plastics, metals, textiles and inorganic remains like construction waste etc.

Sampling

Leachate monitoring was carried out by means of samples taken from leachate pond (Figures 1 and 2). The samples were collected with a sampler from the surface of the leachate pond. Analyses of the leachate samples were carried out twice a year. The assessed parameters of the leachate in the research included the following heavy metals: Hg, Zn, Ni, Cr^{6+}, Cd, Pb.

In order to determine the parameters of heavy metals in groundwater and surface water, monitoring wells and sampling points were used (Figure 2). The samples were collected from the wells in a dynamic state, after short-time drainage (approx. triple exchange of water in the well, or to stable state). Sampling methods were in accordance with the Czech National Standard ČSN ISO 5667, part 11 (groundwater). Surface water samples were collected from the surface of a nameless stream – left tributary stream of Točnického. All samples were collected into airtight glass or plastic containers based on the analyzed component and immediately transported to accredited laboratory for analysis.

Sampling points and monitoring wells for leachate, groundwater and surface water were defined in the area of the landfill. Their distribution and frequency were established by an accredited laboratory. The allocation of sampling points and monitoring wells for the assessment of leachate, groundwater and surface water at the landfill MSW Štěpánovice is shown in Figure 2.

Samples of leachate, groundwater and surface water were collected within time period of 9 years (April 2002 – August 2010). The analyses of the samples were carried out by the company SOM, s.r.o., Mníšek pod Brdy and Health Institute seated in Pilsen, the Centre of laboratories Klatovy (accreditation No. 150/2007), Czech Republic.

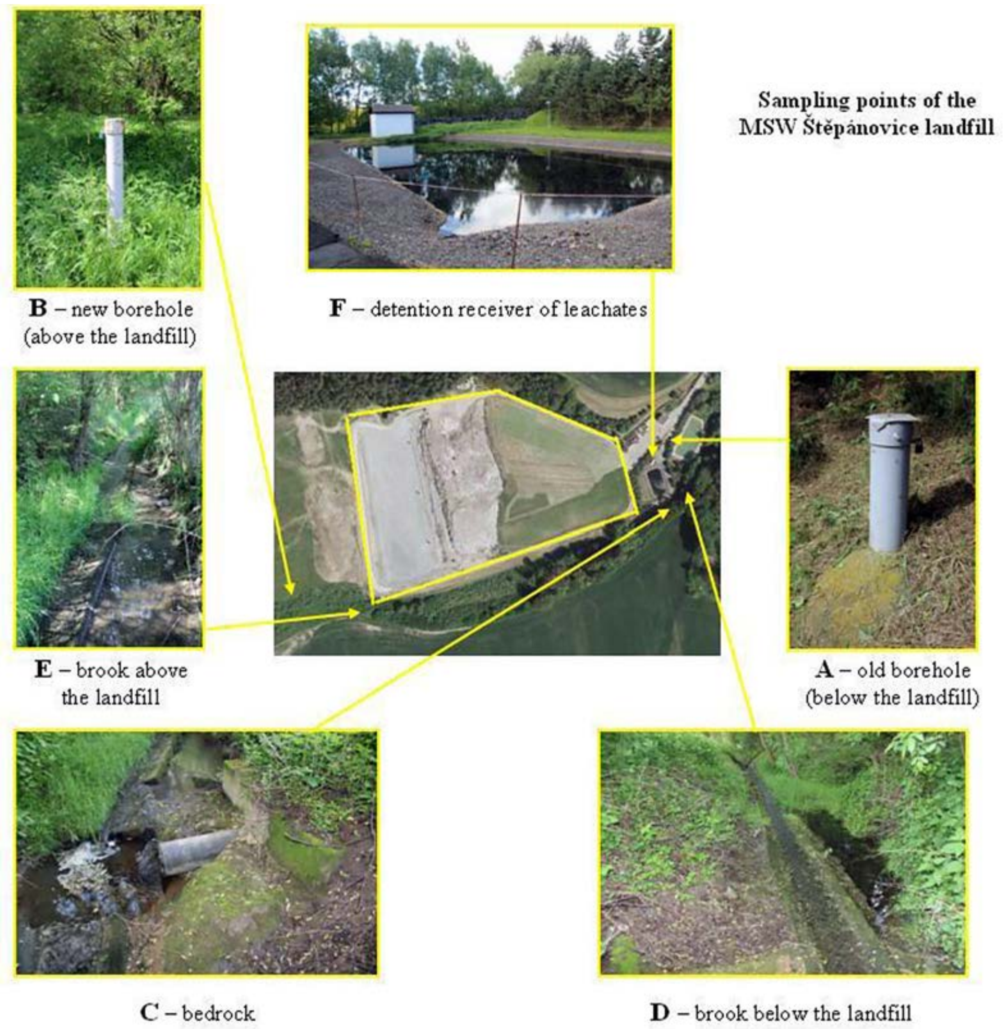


Figure 2. Scheme of sampling points and monitoring wells at MSW landfill Štěpánovice

RESULTS

Monitoring of landfill leachate, surface and groundwater quality

The landfill is subjected to monitoring of surface water, groundwater and leachate at regular intervals. Samples of groundwater and surface water are taken from five sampling points, which are marked as follows (designation – characterization): A – old borehole (below the landfill), B – new borehole (above the landfill), C – bedrock, D – brook below the landfill (distant less than 2 m from the former place) and E – brook above the landfill. Samples of leachate (F) are taken from the detention receiver of leachate. Thus, there are altogether six sampling points. The research was divided into three parts. The specifications of particular parts of the research are described in Table 1.

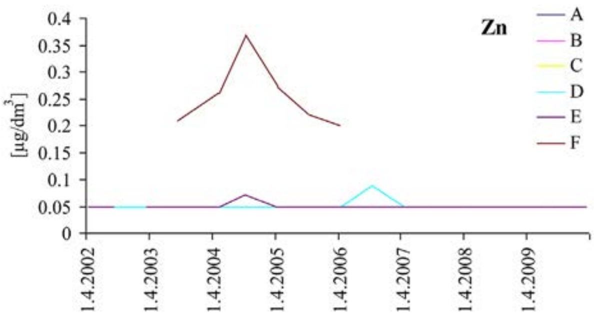
Table 1. Specification of particular parts of the research

Research	Specialization	Parameters [μg/dm³]	Period	Sampling point
I	Leachate water	Cd	4/2005–4/2006	F
		Cr^{6+}	5/2003–4/2006	
		Hg	5/2003–8/2010	
		Ni	5/2003–10/2004	
		Pb	4/2005–3/2010	
		Zn	5/2003–4/2006	
II	Groundwater	Cd	4/2005–3/2010	A, B, C
		Cr^{6+}	4/2002–3/2010	
		Hg	4/2002–8/2010	
		Ni	4/2002–10/2004	
		Pb	4/2005–3/2010	
		Zn	4/2002–3/2010	
III	Surface water	Cd	4/2005–3/2010	D, E
		Cr^{6+}	4/2002–3/2010	
		Hg	4/2002–8/2010	
		Ni	4/2002–10/2004	
		Pb	4/2005–3/2010	
		Zn	4/2002–3/2010	

The obtained values were assessed pursuant to the criteria set forth in the Methodological Guide of the Ministry of Environment of the Czech Republic – „Soil and Groundwater Contamination Criteria“ (1996) and according to the Czech National Standard ČSN 75 7221 „Classification of Surface Water Quality“.

All samples were monitored for parameters required by valid legislation as well as for the occurrence of heavy metals: Zn, Cr^{6+}, Hg, Ni, Cd and Pb. Figures 3–8 illustrate the courses of heavy metal concentrations (μg/dm^3) from all six sampling points in the period 2002–2010 and the limits for particular water categories according to the legislation.

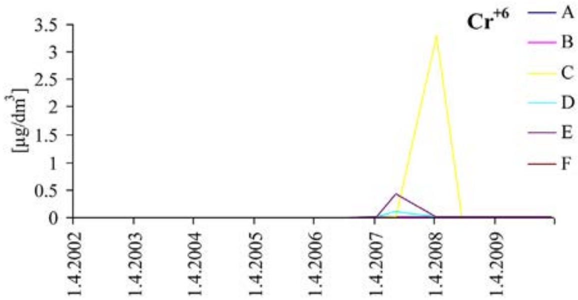
The course of the measured values and the limits for Zn (μg/dm^3) in the reporting period for all sampling points are shown in Figure 3. The value of Zn concentration ranged from 0.05 to 0.37 μg/dm^3. The highest values were obtained at sampling point F. The limits for Zn stipulated by legislation were not exceeded at any of the six sampling points. The limits for particular types (categories) of water were not exceeded for this parameter.



Zn	Limit [μg/dm^3]
Groundwater	150
Surface water	15

Figure 3. Concentrations of heavy metal (Zn) from the sampling points in the period 2002–2010 [Vaverková and Adamcová, 2014]

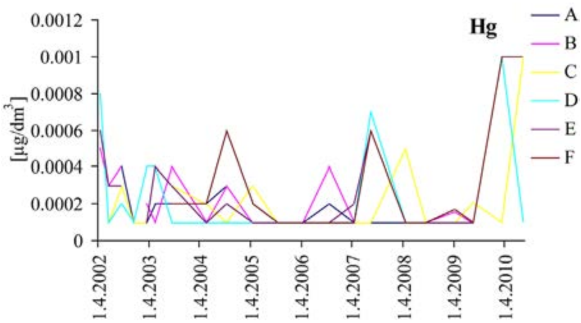
The course of the measured values and limits for Cr^{+6} (μg/dm3) in the reporting period for all sampling points is shown in Figure 4. The value of Cr^{+6} concentration ranged from 0.01 to 3.3 μg/dm^3. The highest values were observed at sampling point C. At five sampling points (A, B, D, E, F) the values of Cr^{+6} did not exceed the limits stated by legislation. The limits for particular types (categories) of water were not exceeded for this parameter. Only in one sample from 8 April 2008 at sampling point C (bedrock – the groundwater) the value defined by legislation (Methodological Guide of the Ministry of Environment of the Czech Republic – „Soil and Groundwater Contamination Criteria“ [1996], 1 μg/dm^3 was exceeded; the measured value reached 3.3 μg/dm^3. Considering the long term monitoring (9 years), it can be stated that the average value for Cr^{+6} (0.177 μg/dm^3) at sampling point C did not exceed the required limit.



Cr^{+6}	Limit [μg/dm^3]
Groundwater	1
Surface water	5

Figure 4. Concentrations of heavy metal (Cr^{+6}) from the sampling points for the period 2002–2010 [Vaverková and Adamcová, 2014]

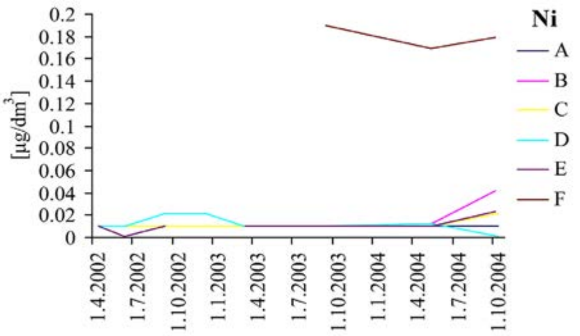
Another monitored heavy metal was Hg. The course of measured values and limits for Hg (μg/dm^3) in the reporting period for all sampling points is illustrated in Figure 5. The value of Hg concentration oscillated between 0.0001 and 0.001 μg/dm^3. The limits for Hg stipulated by legislation were not exceeded at any of the six sampling points. The limits for particular types (categories) of water were not exceeded for this parameter.



Hg	Limit [μg/dm^3]
Groundwater	0.1
Surface water	0.05

Figure 5. Concentrations of heavy metal (Hg) from the sampling points for the period 2002–2010 [Vaverková and Adamcová, 2014]

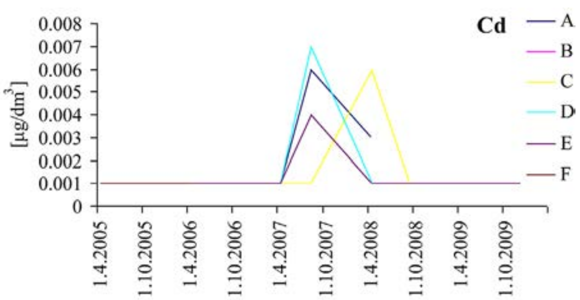
Besides Zn, Cr^{+6} a Hg the heavy metal Ni was examined. The course of measured values and limits for Ni (μg/dm^3) in the reporting period at all sampling points is shown in Figure 6. The value of Ni concentration ranged from 0.001 to 0.19 μg/dm^3. The highest figures were recorded at sampling point F. The limits for Ni stipulated by legislation were not exceeded at any of the six sampling points. The limits for particular types (categories) of water were not exceeded for this parameter.



Ni	Limit [μg/dm³]
Groundwater	20
Surface water	5

Figure 6. Concentrations of heavy metal (Ni) from the sampling points for the period 2002–2004 [Vaverková and Adamcová, 2014]

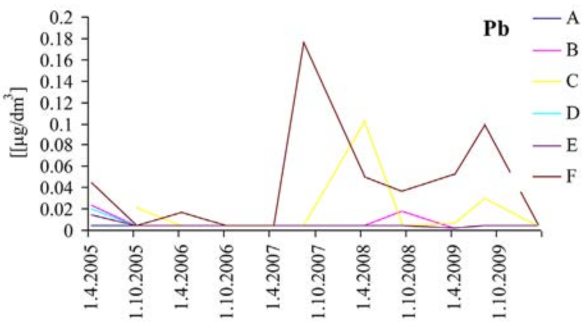
The course of the measured values and limits for Cd (μg/dm^3) in the reporting period for all sampling points is shown in Figure 7. The value of Cd concentration ranged from 0.001 to 0.007 μg/dm^3. The highest values were observed at sampling point C. The limits for Cd stipulated by legislation were not exceeded at any of the six sampling points. The limits for particular types (categories) of water were not exceeded for this parameter.



Cd	Limit [μg/dm³]
Groundwater	1.5
Surface water	0.1

Figure 7. Concentrations of heavy metal (Cd) from the sampling points for the period 2005–2010 [Vaverková and Adamcová, 2014]

The last examined heavy metal was Pb. The course of measured values including the limits for Pb (μg/dm^3) in the reporting period for all sampling points is demonstrated in Figure 8. The value of Pb concentration ranged between 0.002 and 0.176 μg/dm^3. The highest figures were recorded at sampling point F. The limits for Pb stipulated by legislation were not exceeded at any of the six sampling points. The limits for particular types (categories) of water were not exceeded for this parameter.



Pb	Limit [μg/dm³]
Groundwater	20
Surface water	3

Figure 8. Concentrations of heavy metal (Pb) from the sampling points for the period 2005–2010 [Vaverková and Adamcová, 2014]

CONCLUSION

Monitoring of leachate, groundwater and surface water aiming at determining the concentration of heavy metals (Hg, Zn, Ni, Cr^{6+},Cd, Pb) at the MSW landfill Štěpánovice took place in the years 2002–2010. The values of heavy metals concentration oscillated as follows: Zn (0.05 – 0.37 μg/dm^3), Cr^{+6} (0.01 – 3.3 μg/dm^3), Hg (0.0001 – 0.001 (μg/dm^3), Ni (0.001 – 0.19 μg/dm^3, Cd (0.001 – 0.007 μg/dm^3) a Pb (0.002 – 0.176 μg/dm^3).

The measured data show that the concentrations of heavy metals meet the limits provided by law. Under the current landfill operation mode, the results of measurements do not indicate any negative impact on the quality of surface water, groundwater or leachate water.

This conclusion can be additionally supported by the results obtained within biological monitoring. Biological monitoring with the use of bioindicators has been taking place in the surroundings of Štěpánovice landfill since 2007 (still ongoing).

In the rainwater reservoir (Figure 1) the occurrence of *Triturus vulgaris* species was recorded. It is necessary to mention that its occurrence may reflect correct operation of the landfill considering the sensitivity of *Triturus vulgaris* to the environment. This species is legally protected and in accordance with the Regulation No. 395/1992 Coll. belongs to highly endangered species. Its presence in the rainwater reservoir water proves clarity of this water and shows that no contamination of water by leachate from the landfill or from leachate pond takes place.

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