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title: **The grounds for determining additional index parameters in the monitoring process of water environment in the vicinity of municipal waste landfills**

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THE AIM OF THE STUDY

Municipal waste landfills classified as other than hazardous or neutral frequently constitute a direct or indirect threat for the soil and water environment. Contamination of the environment results from malfunctioning or inadequate conservation of landfills which are still both in and out of operation. Old landfills constitute a threat for the environment as they frequently have no artificial sealing at the bottom of the facility, the only basal sealing is constituted by substratum horizons. Municipal waste landfills which may not be adapted to comply with legal requirements in force should be closed down and their negative impact on the environment eliminated. Conditions connected with the location of each landfill and methods of conserving and inspecting it have to be individually identified and adjusted.

Monitoring the impact zones of individual sites is the basic element of inspections carried out in order to determine safety levels. The range of monitoring and its frequency are subject to legal regulations, however it is crucial to select additional specific parameters characteristic for individual landfills in order to include them in the programme of control studies. Studies of leachate from municipal waste landfills and environmental monitoring carried out by the authors of this paper earlier indicate that such sites may contaminate waters to an extent which exceeds prescribed values (Klojzy-Karczmarczyk et al., 2003; Brudnik et al., 2006; Witkowski, 2009).

According to regulations currently in force it is obligatory to monitor among other things water pH, electrical conductivity and selected metals. However, these parameters and their variability may in some cases go unnoticed or may result from the impact of other facilities and their values are the effect of overlapping of various anthropogenic or natural factors. Additional indicators for the purposes of soil and water monitoring potentially impacted by municipal waste landfills should be determined based on an analysis of landfill specificity and of a study of selected environmental parameters (e.g. the composition of leachate water and surface water) in the potential impact zone of a given facility.

STUDY RESULT INTERPRETATION

The existing facilities and their actual impact on the environment have been analysed. Over the period of several years the authors have conducted studies of the quality of surface waters and groundwaters in the vicinity of several landfills where deposited municipal waste is obviously a contaminant.

In the presented paper the quality of surfaces water and groundwaters were analysed in the impact zone of two municipal waste landfills currently in operation in Małopolska region and one landfill which is out of operation Podkarpacie region. The authors are of the opinion that the obtained study results and an analysis of partial archive data have allowed to indicate the necessity of establishing additional contamination indices around municipal waste landfills. They should be considered specific indicators, characteristic for the surrounding areas of such landfills.

The quality of surface water was analysed in the impact zone of a municipal waste landfill located in Małopolska region, not far from Krakow, on a salt post-mining site. The landfill is situated in a natural depression and partially in a hollow resulting from ground subsidence due to the leaching of rock-salt mined until late 1990s. The potential source of contamination of the water environment in the discussed area is connected with the operation of municipal waste

landfill and particularly with two closed down phases of its operation. Potentially migrating leachate constitutes a source of water contamination in the catchment basin of the river Malinówka adding to contamination resulting from former salt mining. The two first operating phases of the landfill have no additionally sealed base but have already been reclaimed. The phase which is currently in operation has been protected with additional synthetic insulation (Brudnik et al., 2006).

The results of studies conducted between 2008 – 2009 around the landfill indicate that the surface water is contaminated with chlorides and organogenic compounds which confirms indices recognised as characteristic. Figure 1 presents the variability of characteristic contamination indices of the river Malinówka waters in the potential impact zone of the landfill in locations above and below the facility. In the location below the landfill, an increase of electrical conductivity of water corresponding to mineralisation and ammonia nitrogen and chloride content has been clearly observed.

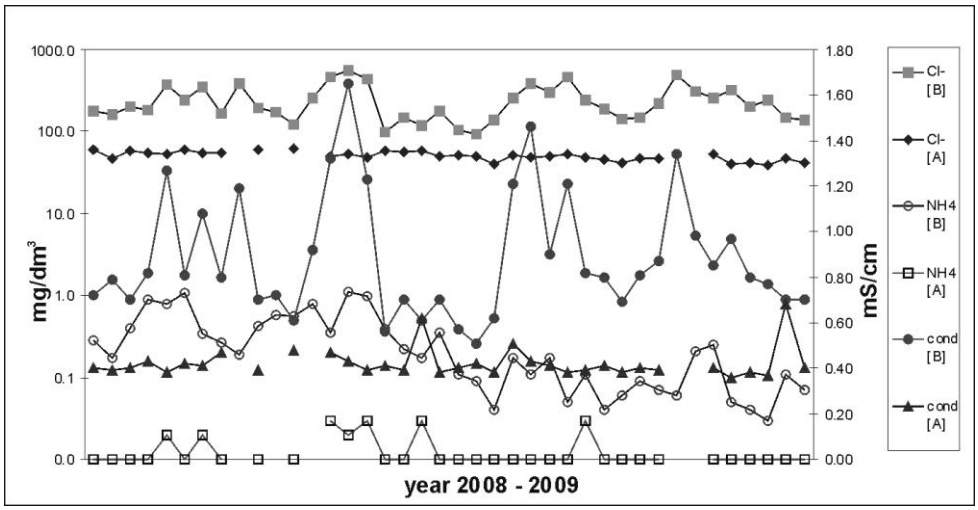

Figure 1. The changing values of characteristic surface water contamination indicators in the impact zone of a municipal waste landfill (A – site located above the facility; B – site located below the facility).

In the course of the river Malinówka water analysis, concentration of indices regarded as obligatory in the monitoring process has also been determined. Over the period of the last two years no increase of any of these parameters has been observed at the location below the landfill and these values are generally low, often below the detection level (fig. 2, table 1). Based on concentrations of parameters which are regarded as obligatory, it may be considered that there is no negative impact of the municipal waste landfill on the surface water environment. What is puzzling however, is the increase of electrical conductivity at the location below the landfill. This increase is doubtlessly the result of a measured chloride concentration in surface waters, which in this case, may indicate the existence of a negative impact of the analysed landfill.

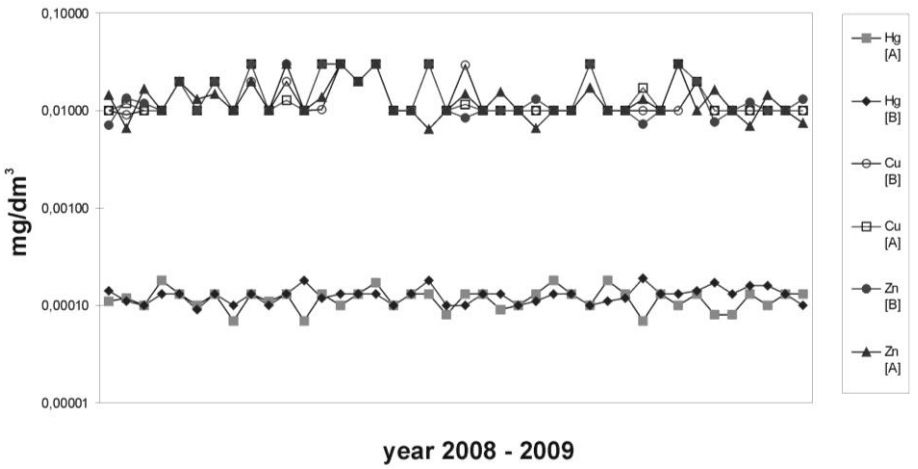

Figure 2. Obligatory indicators parameters in surface waters in the municipal waste landfill impact zone (A – site located above the facility; B – site located below the facility).

The quality of groundwaters was analysed in the impact zone of two municipal waste landfills located in two different regions. The access to the investigated environment in case of groundwaters is technically difficult, therefore the number of groundwaters quality measurements is significantly smaller than the number of surface water measurements presented above.

The municipal waste landfill located in the Małopolska region is an operating facility. It comes in contact with Carboniferous period deposit outcrops, and is naturally unprotected from leachate penetration. However, the landfill has been sealed with synthetic material (bentonite padding and HDPE foil geomembrane).

Groundwaters quality studies conducted between 2008 – 2009 indicated a general increase of electrical conductivity in the study borehole located at the outflow of these waters (Fig. 3).

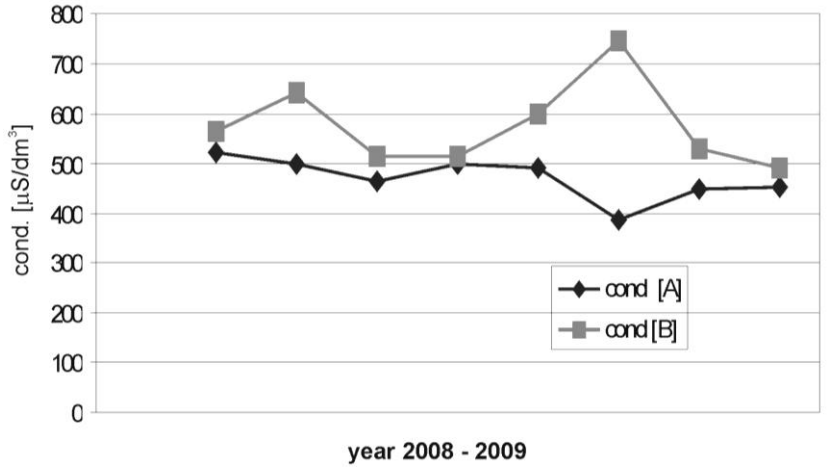

Figure 3. Electrical conductivity in groundwaters in the impact zone of municipal waste landfills (A – observation borehole at inflow; B – observation borehole at outflow of water from the landfill).

The concentration of indicators regarded as obligatory, indicated no increase at the same observation borehole (table 1). Studies of additional characteristic indicators were not conducted. It is therefore not possible to establish the reason for increased mineralisation of water leaching from the landfill area.

Table 1. Water environment contamination indicators in the impact zone of municipal waste landfills.

index	surface WATERS		groundWATERS			
	Malinówka stream*		Quaternary aquifer**		Carboniferous aquifer ***	
	above landfill	below landfill	at inflow	at outflow	at inflow	at outflow
OBLIGATORY INDEX PARAMETERS						
electrical conductivity of water [μS/cm]	416	879	no	no	470	575
[pH]	1.07.1958	1.07.1989	1.06.1995	1.07.2014	1.07.1930	1.07.1941
chromium [mg/dm^3]	<0.01	<0.01	no	no	<0.01	<0.01
zinc [mg/dm^3]	0.025	0.031	no	no	<0.01	<0.01
cadmium [mg/dm^3]	<0.001	<0.001	no	no	<0.001	<0.001
copper [mg/dm^3]	0.02	0.03	no	no	<0.005	<0.005
lead [mg/dm^3]	<0.01	<0.01	no	no	<0.005	<0.005
mercury [mg/dm^3]	0.00015	0.00015	no	no	<0.001	<0.001
ADDITIONAL INDEX PARAMETERS						
chloride [mg/dm^3]	46	238	26,5	29,6	no	no
ammonium ion [mg NH_4^+/dm^3]	0.01	0.09	no	no	no	no
nitrate ion [mg NO_3^-/dm^3]	1,78	2,85	4,54	8,95	no	no

no – not determined

* - landfill in the vicinity of Krakow, research between 2008 – 2009; mean values

** - landfill in Podkarpacie region, research between 2002 – 2003; mean values

*** - landfill in Małopolska region; research between 2008 – 2009; mean values

The municipal waste landfill located in Podkarpacie region is out of operation. Studies were conducted between 2002–2003 while it was still in operation in a period when there were no binding legal regulations on monitoring studies. The landfill is located in a natural hollow, in an old river-bed meander. Quaternary sediments in the form of compact loam underlain with river sand are the direct substratum of the landfill. Miocene shaly mud-stone is the substratum of quaternary sediments. The landfill has not been sealed with synthetic material, so there is a potential leachate migration and therefore a real threat to groundwaters environment. There are no natural surface streams in the vicinity. Currently the landfill dome is being sealed and the site is being reclaimed.

Figure 4 presents the variability of indice parameters in groundwaters of the first water-bearing horizonl in the impact zone of the closed landfill. The study was conducted to obtain additional parameters considered by the authors of the work as specific indicators. In each of the investigated series of samples there is a marked increase in chlorides and nitrates in each of the two observation boreholes located at water outflow from the landfill. Other parameters were not determined, however on the basis of the obtained results of chloride and nitrate concentration, negative impact of landfill on the groundwaters environment may be concluded.

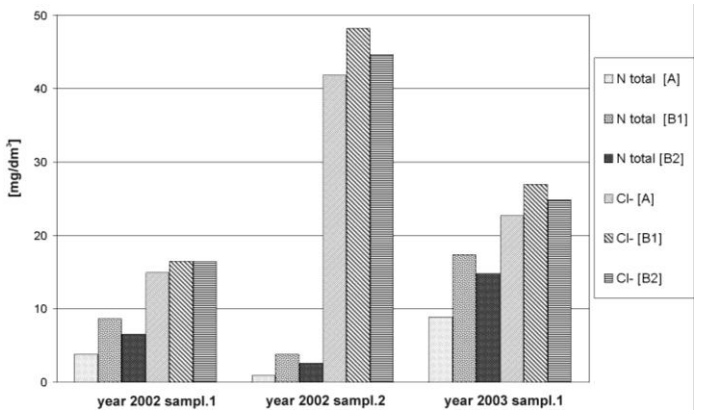

Figure 4. Variability of characteristic indicators of groundwaters contamination in the impact zone of municipal waste landfill (A – observation borehole at inflow; B – observation borehole at outflow of water from the landfill).

Table 1 contains concentrations of indicators considered obligatory and specific, characteristic for the quality of water environment in the potential impact zone of municipal waste landfill. The table contains average values for all the samples gathered in the subsequent periods from the three analysed landfills.

CONCLUSIONS

Studies have indicated that there is a close relationship between the location of landfills and areas with increased characteristic parameters which have not been selected for obligatory analysis. Undoubtedly chlorides and nitrogen compounds are among specific indicators of possible negative impact of municipal waste landfills on the soil and water environment and they may not be neglected. The results of studies conducted in the impact zones of the existing facilities therefore justify the necessity to extend the scope of monitoring studies. The studies extended in such a manner reflect the actual threats for the environment.

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