

# ASSESSMENT OF THE POSSIBILITY OF METAL MIGRATION FROM A MUNICIPAL WASTE SITE

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**Abstract.** Mobility of metals in a municipal waste site was studied. Solubility of metals in the material collected in the landfill was low at the neutral and slightly alkaline pH's, and was substantially increased at the acid pH. The slightly alkaline or neutral pH should be maintained within landfill in order to reduce mobility of metals.

mobilization from the solid samples under varying pH's and d) metal solubility in sodium pyrophosphate (an organically bound metal extractant). Because of similarity of all municipal waste sites, the importance of metal mobility study is not confined to this specific landfill, and can be useful in the assessment of the possibility of ground water contamination.

## INTRODUCTION

### Description of Site

The investigated municipal waste site is located in Jawidz (Poland) in an open sand pit. A cool marine climate with annual rainfall of 500 to 750 mm and average January and July temperatures of -4°C and +16°C is typical for this region. The bottom of the landfill is 9.5 m below the level of the surrounding terrain and about 1 m above the ground water level. Sandy materials surround the landfill. The bottom and walls of the pit are lined with plastic liner. The bottom plastic liner is protected against damage by a layer of sand 0.5 m thick. The walls of the pit are lined with sand and concrete.

Municipal wastes are placed in horizontal layer and compacted by bulldozers. Wastes are then covered with chlorinated lime and a thin layer of soil before the next layer of waste is deposited and the whole process is repeated. Part of the landfill is already finished (this is referred to as the old part). This part is covered with fly ash. Part of the landfill is used currently (this is referred to as the new part) and another part is reserved for future use.

The wells supplying water to local farmers are located 500 m from the landfill which may have a direct influence on potable water quality. Contamination with metals is a major concern. The objective of the study was the assessment of the possibility of metal migration from the municipal waste site to the ground water based on a) the total metal content of solid samples collected from the waste site, b) metal concentrations in water percolating through the waste, c) laboratory batch studies of metal

## MATERIALS AND METHODS

In order to characterize sandy material typical for the landfill site, samples were taken at a depth of 120-150 cm. Samples of the waste material were collected from the 0-40 cm surface layers of the new and old parts of the landfill and from the two bottom sectors. One of the sectors was in immediate contact with solid waste and remained under the influence of water percolating through the layers of waste while the other sector collected liquid waste of unknown origin. Ten point-samples were collected at each location and combined to make one representative sample.

Samples were air dried, homogenized in a porcelain mortar and sieved through a 2 mm plastic screen. The pH of samples was measured in water suspension and in 1 N KCl (m/v 1:2.5) after 24 hours of equilibration. Organic matter was determined by loss on ignition. Total concentrations of Fe, Mn, Ni, Cu, Pb, Cr and Zn in the samples collected in the landfill and in the sand surrounding the landfill were determined in the solid samples (without acid digestion) using spark emission spectrometry with Pd as an internal standard. Organically bound metals were extracted using 0.1 M sodium pyrophosphate with solid to solution ratio m/v 1:2. The extraction procedure involved shaking samples for two hours followed by equilibration for 24 hours and a further two hours of shaking. Metals in the filtrate were determined by atomic absorption spectrophotometry (AAS).

Metal solubility studies at various pH's were carried out on samples collected in the old and new parts of the landfill.

Samples were mixed with deionized water ( m/v 1:2) and then the pH of the suspension was adjusted by titration with 1M HNO<sub>3</sub> + 1M H<sub>2</sub>SO<sub>4</sub> to values of 3, 4, 5, 6 and 7 for five consecutive days until pH stabilized, after which solubilized metals were determined in the filtrate using AAS. The 400 mL of the percolate water collected in the landfill was evaporated in a water bath. The residuum was mineralized with concentrated HNO<sub>3</sub> and hydrogen peroxide, diluted with deionized water up to 50 mL, and analyzed on AAS for Fe, , Ni, Cu, Pb, Cr and Zn.

## RESULTS

The total concentrations of Fe in samples collected from different points of the landfill were not much higher than that of surrounding sand, but concentrations of the other metals were one to two orders of magnitude higher than in sand (Table 1). However, the sand had extremely low levels of all investigated metals. Landfill metal levels were in many cases within the ranges typical for natural terrestrial environments (Kabata et al., 1992). The sandy material had a very low sorption capacity of 1.33-3.15 meq /100g and a pH of 4.2-5.2. These conditions along with a high water permeability would promote metal migration.

Samples from the old part of the landfill had the highest levels of Fe and Mn. It is not clear if this is a result of physical and chemical homogenization and dissolution of the waste or if it is related to the chemical composition of the fly ash which was applied on the surface after the filling of this part of landfill had been finished. The landfill materials are characterized by high organic carbon content and an alkaline pH resulting from lime application (Table 1).

Laboratory batch studies showed that, at neutral and slightly alkaline pH's, metals were immobile except for Ni, Fe and Mn in the old part of the landfill and Mn in the new part (Table 2). Solubility of all metals increased with decreasing pH. Metal mobility under acid pH in the samples from the new part of the landfill decreased in the following order Zn> Mn> Ni> Cu> Cr> Pb> Fe while in the old part the order differed; Ni> Fe> Mn> Zn> Cu> Cr> Pb. Solubility of Pb and Cr was low even under very acid pH. A considerable part of Zn in all samples was associated with organic matter (Table 3). The other metals were to various degree associated with organic matter, depending on the metal and the location of the place where samples were collected. Higher amounts of organically bound metals were found in the bottom part of the landfill suggesting that, with alkaline pH promoting solubility of

**Table 1. Total Metal Concentrations, pH and Organic Matter Contents in the Waste Samples, the Sandy Ground Surrounding the Landfill and Percolated Water Collected in the Landfill**

Sampling Area Location	Fe	Mn	Pb	Cr	Cu	Zn	Ni	pH <sub>water</sub>	pH <sub>KCl</sub>	Organic Matter
The new part of landfill (mg/kg)	1.0 %	165	68	40	22	47	24	8.3	8.2	5.0 %
The old part of landfill (mg/kg)	8.0 %	2063	78	72	461	367	110	7.5	7.5	7.8 %
Bottom of landfill (mg/kg)	1.2 %	235	258	49	127	201	83	8.4	8.4	9.5 %
Liquid waste deposit (mg/kg)	0.9 %	518	163	45	52	402	40	7.6	7.5	5.7 %
Sand (mg/kg)	0.3 %	20	3	3	1	10	1	5.2	4.4	0.0 %
Percolated water (mg/L)	12.35	0.41	0.35	1.03	1.53	3.79	0.64	7.6		
Guidelines for groundwater*	-	-	0.20	-	0.20	0.80	0.20			
Maximum admissible concentration in drinking water (CEC)**	0.30	0.05	0.05	0.05	1.00	5.00	0.05			

\* Highly elevated levels according to the Dutch Guidelines for Metal Concentrations in Groundwater ( source; U. Ewers, 1991)

\*\* Council of the European Communities (source; U. Ewers, 1991)

organic compounds, metals migrate in the form of organic complexes. Metal concentrations in water collected in the landfill representative of real leaching conditions were 12.35 (Fe), 0.41 (Mn), 0.35 (Pb), 1.03 (Cr), 1.53 (Cu), 3.79 (Zn) and 0.64 (Ni) mg L<sup>-1</sup>, and can not be considered very high according to groundwater quality guidelines or

**Table 2. Metal Solubility at Various pH's in the Waste Samples Collected in the Landfill**

Element	pH				
	3.0	4.0	5.0	6.0	7.0
The new part of the landfill					
Fe mg/L	7.1	0.2	0.1	0.0	0.0
% *	0.14	0.05	0.0	0.0	0.0
Mn mg/L	50.9	40.1	10.0	4.5	3.4
% *	61.7	48.6	12.1	5.5	4.1
Pb mg/L	0.23	0.00	0.00	0.00	0.00
% *	0.67	0.0	0.0	0.0	0.0
Cr mg/L	0.25	0.08	0.00	0.00	0.00
% *	1.25	0.4	0.0	0.0	0.0
Zn mg/L	19.7	8.6	0.03	0.00	0.00
% *	83.8	36.6	0.1	0.0	0.0
Cu mg/L	0.45	0.12	0.06	0.04	0.01
% *	4.1	1.1	0.5	0.4	0.1
Ni mg/L	1.47	1.59	0.04	0.00	0.00
% *	12.3	13.3	0.3	0.0	0.0
The old part of the landfill					
Fe g/L	13.35	10.87	5.56	1.86	0.60
% *	33.4	27.2	13.9	4.7	1.5
Mn mg/L	220.0	200.0	141.0	71.0	39.0
% *	21.6	19.6	13.0	6.9	3.8
Pb mg/L	0.10	0.00	0.00	0.00	0.00
% *	0.3	0.0	0.0	0.0	0.0
Cr mg/L	3.09	0.85	0.03	0.00	0.00
% *	8.6	2.4	0.1	0.0	0.0
Zn mg/L	27.60	21.90	7.40	1.55	0.28
% *	15.0	11.9	4.0	0.8	0.2
Cu mg/L	32.8	7.93	0.06	0.03	0.01
% *	14.2	3.4	<0.1	<0.1	<0.1
Ni mg/L	39.60	33.30	18.00	9.50	2.40
% *	72.0	60.5	32.7	16.6	4.4

\* soluble form expressed as percentage of the total content

**Table 3. Organically Bound Metals in the Samples Collected in the Landfill Expressed as Percentage of the Total Metal Contents**

Sampling area location	Fe	Mn	Pb	Cr	Zn	Cu	Ni
The new part	0.6	1.8	0.9	1.7	28.3	7.0	1.2
The old part	0.5	1.3	0.6	6.8	23.2	0.3	2.8
Bottom	5.7	3.2	1.6	5.0	38.1	9.7	13.6
Liquid waste deposit	3.3	1.8	2.7	3.7	16.8	17.1	8.7

drinking water standards in the case of Cu and Zn (Ewers, 1991). The water had an alkaline pH (7.6).

## CONCLUSIONS

Batch laboratory studies confirmed that at a moderately acid to neutral pH, solubility of investigated metals in the waste material was low, except for Fe, Mn and Ni in the old part of the landfill. This corroborates with relatively low metal concentrations found in the percolated water collected in the landfill. Although sandy material surrounding the landfill would not act as a protective barrier against metal migration into ground water, the construction of the landfill and the high pH of the waste material are expected to be sufficient protection against metal contamination of groundwater.

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