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# CHEMICAL COMPOSITION OF LEACHATES ON EXPLOITED LANDFILL SITE

***Grzegorz Przydatek***
*State Higher Vocational School in Nowy Sącz*

***Summary***

Results of analyses of underground waters on a municipal landfill site conducted in 2004-2008, prior to leachate cleaning were presented and discussed in the paper. The sewage quality analysis comprised pH, electrolytic conductivity, TOC, $Cr^{+6}$, Pb, Cd, Cu, Hg, Zn and PAHs. Results of leachate water testing were compared with standard values and subjected to comparative analysis taking into consideration also atmospheric precipitation amount. The aim of the paper was to assess the leachate water quality in conditions of exploited municipal landfill. The analyzed waters were characterized by variability of composition evidenced by increasing pH values, electrolytic conductivity and heavy metal concentrations (Cr, Hg) total organic carbon (TOC) and PAHs, but also by a decline in heavy metal contents (Pb, Cd, Cu and Zn).

## INTRODUCTION

Municipal landfills are the objects whose existence involves a potential hazard for the surrounding environment due to wastes with various composition and decomposition time deposited there. Potential threat for water environment results from biochemical decomposition of wastes but also from various ways in which the landfills are organized (Przydatek G., 2013). The main factors of water environment pollution during the landfill exploitation include leachates, i.e., rainwater migrating through the waste deposit and washing out dissolved organic and mineral substances. Because the composition of leachates is connected with chemical composition of wastes and also with the age and technology of

their storage, organic and inorganic pollution is increasing (Olańczuk-Neyman K. *et al*.2000, Szpadt R., 2005). According to Rosik-Dulewska (2011) organic and inorganic component content in leachates depend of the amount of water flowing through them and their susceptibility to solving. Leachates from so called "young landfills" (the age of deposited wastes does not exceed 5 years) are characterized by a considerable content of organic substances. With prolonging period of landfill exploitation the content of organic substances is decreasing due to the ongoing process of their decomposition, whereas the amount of difficult-to-decompose substances increases. Therefore, so called "old landfills" (the age of deposited waste exceeds 10 years) are characterized by a dominating share of indecomposable fractions, exceeding considerably the share of decomposable compounds (Barbusiński K. *et al*., 2010). Granulometric composition of wastes, the conditions of landfill exploitation and the deposit thickness also influence the leachate composition (Koc-Jurczyk J.,Różak J., 2011). Concentrations of heavy metals (cadmium, zinc, chromium, copper, nickel and lead) and polycyclic aromatic hydrocarbons in leachates should be considered disadvantageous. Presence of the above-mentioned heavy metals after Szyc (2003) disturbs biological equilibrium but also slows down the process of water self-purification. Presence of PAHs in the environment is strictly connected with pollutant emission to the atmosphere due to fuel burning. The main sources of PAHs include emission of pollutants from coal burning indoor cooking fires and communication routes (Kuna, 2011). Elevated heavy metal content may be particularly noticeable on "young" landfills, which is accompanied by an acid phase of fermentation (Jurczyk Ł., 2012). Due to high loads of many kinds of pollutants, leachates from municipal landfills are commonly regarded among the sewage which most strongly affects the environment (El-Fadel M. *et al*., 2002).

The aim of the paper is assessment of leachate water composition at the stage of municipal landfill exploitation.

## METHODS

Results of measurements of precipitation amount for the years 2005-2008 presented in the paper comes from a Hydrological-Meteorological station, representative for the discussed landfill, situated in the Kozienice branch of the Institute of Meteorology and Water Management in Krakow. Samples of leachate water for analyses were collected on the landfill site in a collecting well, i.e., in the place of their gathering prior to treatment. Measurements of pH and electrolytic conductivity were conducted on site (using pH meter and portable conductometer), whereas chemical assessments were done in laboratory conditions, immediately after delivering the collected samples.

The assessments comprised total pollution indices (pH, electrolytic conductivity, total organic carbon – TOC) and chemical pollution indices ($Cr^{+6}$, Pb, Cu, Cd, Hg and Zn) and organic contamination (polycyclic aromatic hydrocarbons – PAHs). These assessments were made periodically, once per sector in the years 2005-2008.

Studied index parameters in leachate water were compared with limit values stated in the Decree of the Minister of Building of 14 July 2006 on fulfillment of duty by industrial sewage suppliers and principles of sewage supply to sewer systems (Dz. U.2006 Nr 136, poz.964).

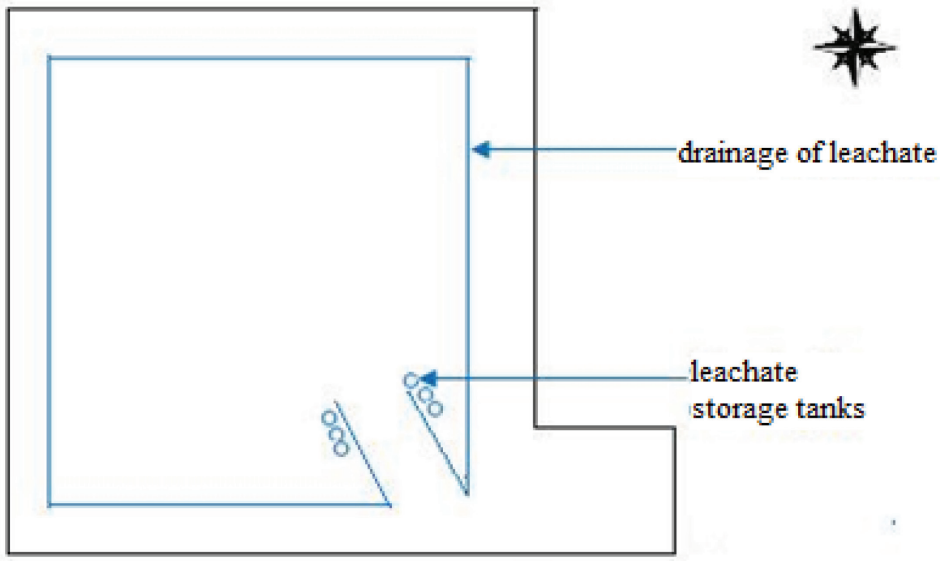


**Figure 1.** Drainage system at municipal landfill site in Guzów

## LOCATION OF THE LANDFILL

The analyzed landfill of wastes other than dangerous and neutral is situated in Guzów, the southern part of the Mazowieckie voivodship, in the Orońsko commune on the Radomska Plain, which is a part of the South Mazovia Uplands macroregion.

The surface of terrain where the landfill is located is a plain with a slight inclination towards north-east. Its total area is 2.04 ha, whereas a sector's area is 1.30 ha at geometric volume of 51,350 $m^3$. The investigated object is situated at a distance of c.a. 850 m from a housing complex and farm buildings, and watercourses (Przydatek G., 2009).

## CONSTRUCTION AND EXPLOITATION OF THE LANDFILL

The landfill comprises one sector of aboveground and belowground character due to its location in the depression. The object is situated in an excavation after sand and gravel exploitation. The basin of the excavation is surrounded by peripheral scarps.

The natural landfill substratum are deposits with permeability coefficient $k = 10^{-5}$cm·s$^{-1}$ and the bottom sealing is mineral ground, 0.5-m thick loam. Moreover, sandy loams with rill stones of gray or brown colouring were found in the bottom of the analyzed object in some places under a thin sand layer. In this region the aquifer horizon occurred at the depth from 11.5 to 13.3 m below ground level in the Upper Cretaceous deposits developed as limestone and marls. The direction of underground water flow in the landfill area is from south-east towards north-west (Przydatek G., 2009).

The drainage system comprises drainage lines and holding tanks (Przydatek G., 2012a). The analyzed landfill possesses a circumferential leachate drainage system constructed of 150-mm diameter ceramic filters placed in the bottom of the bowl along the scarps with 3% inclination towards the collecting wells. The drainage system of precipitation waters permeating through the waste block is situated over the mineral sealing (Fig. 1).

The quantity of deposited wastes in 2005-2008 fluctuated from 2698.2 Mg to 3386.20 Mg at an average of 3079.93 Mg. The highest proportion (79.19%) in the deposited waste volume were mixed municipal solid wastes, whereas stabilized municipal sewage sludge had the lowest share of 0.57%. Total volume of the deposited wastes after about 14 years of the landfill exploitation was 27 000 m$^{-3}$, which made up 88% of the sector filling at the density coefficient $I_s = 0.4$ and the deposit thickness 1.5 m (Przydatek G., 2012b).

## RESULTS AND DISCUSSION

### Precipitation

Results of measurement of precipitation amount registered in 2005-2008 were compiled in Tables 1 and 2.

**Table 1**. Amount of atmospheric precipitation in 2005-2006

| Year | 2005 | | | | 2006 | | | |
|---|---|---|---|---|---|---|---|---|
| Period | Q1 | Q2 | Q3 | Q4 | Q1 | Q2 | Q3 | Q4 |
| Precipitation total (mm) | 120.4 | 146.9 | - | - | 75.8.6 | 115.6 | 151.0 | 86.0 |

Source: Author's own studies

**Table 2**. Amount of atmospheric precipitation in 2007 – 2008

| Year | 2007 | | | | 2008 | | | |
|---|---|---|---|---|---|---|---|---|
| Period | Q1 | Q2 | Q3 | Q4 | Q1 | Q2 | Q3 | Q4 |
| Precipitation total (mm) | 124.3 | 145.6 | 164.4 | 54.1 | 81.6 | 113.5 | 164.3 | 105.5 |

Source: Author's own studies

The amount of atmospheric precipitation in the years 2005-2008 fluctuated from 54.1 to 164.4 mm at an average of 118.7 mm. Both the highest and the lowest precipitation was registered in the 3 and 4 quarter of 2007.

**Table 3.** Selected indices analysis of leachate water accumulated on municipal landfill site in Guzów in 2002-2006

| Analyzed indices | Unit of measure | Composition of leachate water | | | | | | Permissible values |
|---|---|---|---|---|---|---|---|---|
| | | 2005 | | 2006 | | | | |
| | | Q 1 | Q 2 | Q 2 | Q 2 | Q 3 | Q 4 | |
| Reaction | pH | 6.83 | 8.14 | 7.3 | 7.4 | 8.1 | 7.4 | - |
| Electrolytic conductivity | $\mu S \cdot cm^{-1}$ | 620 | 1782 | 522 | 1390 | 2100 | 1940 | - |
| Lead | mg $Pb \cdot dm^{-3}$ | 0.012 | 0.08 | 0.029 | < 0.003 | <0.003 | < 0.003 | 1 |
| Cadmium | mg $Cd \cdot dm^{-3}$ | 0.0032 | 0.012 | 0.01 | <0.010 | <0.010 | <0.003 | 0.2 |
| Copper | mg $Cu \cdot dm^{-3}$ | 0.016 | 0.016 | 0.046 | <0.010 | 0.022 | 0.015 | 1 |
| Zinc | mg $Zn \cdot dm^{-3}$ | 0.079 | 0.288 | 0.368 | 0.1 | 0.152 | 0.064 | 5 |
| Chromium | mg $Cr^{+6} \cdot dm^{-3}$ | < 0.001 | 0.001 | < 0.010 | <0.010 | 0.089 | < 0.010 | 0.2 |
| Mercury | mg $Hg \cdot dm^{-3}$ | < 0.0005 | < 0.0005 | < 0.0003 | < 0.0003 | < 0.0003 | < 0.0003 | 0.2 |
| TOC | mg $\cdot dm^{-3}$ | 78.22 | 76.9 | 111 | 17.3 | 157 | 17 | - |
| Total PAHs | mg $\cdot dm^{-3}$ | 0.03 | 0.03 | 0.25 | 0.255 | 0.165 | 0.083 | 0.2 |

Source: Author's own studies

## Leachates

Results of analysis of selected indices of leachate water pollution are presented in Tables 3 and 4. The value of reaction in leachates fluctuated from 6.83 to 9.4 pH at an average of 7.83 pH and the value of electrolytic conductivity ranged from 522 to 8530 $\mu S \cdot cm^{-1}$. The following microelement concentrations were noted in the analyzed leachate water: lead from <0.003 to 0.08mg $\cdot dm^{-3}$, cadmium from < 0.003 to 0.012 mg $\cdot dm^{-3}$, copper from <0.010 to 0.046 mg $\cdot dm^{-3}$, zinc from 0.033 to 0.368 mg $\cdot dm^{-3}$, chromium from <0.001 to 0.089 mg $\cdot dm^{-3}$ and mercury from <0.0003 to 0.0014 mg $\cdot dm^{-3}$.

**Table 4.** Selected indices analysis of leachate water accumulated on municipal landfill site in Guzów in 2007-2008

| Analyzed indices | Unit of measure | Composition of leachate water | | | | | | | | Permissible values |
|---|---|---|---|---|---|---|---|---|---|---|
| | | 2007 | | | | 2008 | | | | |
| | | Q 1 | Q 2 | Q 3. | Q 4 | Q 1 | Q 2 | Q 3. | Q 4 | - |
| Reaction | pH | 7.6 | 7.4 | 7.7 | 8.1 | 7.3 | 9.4 | 7.8 | 9.2 | - |
| Electrolytic conductivity | $\mu S \cdot cm^{-1}$ | 1110 | 2680 | 2880 | 2900 | 2350 | 4540 | 8530 | 2850 | - |
| Lead | mg $Pb \cdot dm^{-3}$ | < 0.003 | < 0.003 | <0.003 | <0.003 | < 0.003 | < 0.010 | <0.010 | < 0.010 | 1 |
| Cadmium | mg $Cd \cdot dm^{-3}$ | <0.003 | <0.003 | <0.003 | <0.003 | <0.003 | <0.003 | <0.003 | <0.003 | 0.2 |
| Copper | mg $Cu \cdot dm^{-3}$ | < 0.010 | <0.010 | 0.01 | 0.01 | 0.018 | 0.013 | 0.014 | < 0.010 | 1 |
| Zinc | mg $Zn \cdot dm^{-3}$ | 0.082 | 0.171 | 0.078 | 0.074 | 0.163 | 0.07 | 0.033 | 0.057 | 5 |
| Chromium | mg $Cr^{+6} \cdot dm^{-3}$ | < 0.010 | 0.032 | < 0.010 | < 0.010 | < 0.011 | 0.022 | 0.015 | < 0.008 | 0.2 |
| Mercury | mg $Hg \cdot dm^{-3}$ | 0.0014 | < 0.0003 | < 0.0003 | < 0.0003 | < 0.0003 | < 0.0003 | < 0.0003 | < 0.0003 | 0.2 |
| TOC | mg $\cdot dm^{-3}$ | 32.3 | 29 | 11 | 20.7 | 64 | 225 | 250 | 20.7 | - |
| Total PAHs | mg $\cdot dm^{-3}$ | 0.116 | 0.249 | 0.136 | 0.136 | 0.189 | 1.14 | 1.05 | 0.314 | 0.2 |

Source: Author's own studies

TOC content fluctuated from 11 to 250 mg $\cdot dm^{-3}$ at the average of 79.29 mg $\cdot dm^{-3}$ and PAH content ranged from 0.03 to 1.14 mg $\cdot dm^{-3}$, at the average of 0.30 mg $\cdot dm^{-3}$.

The results of precipitation measurements in 2005-2008 revealed its lowest total of 428.4 mm in 2006 and the highest value, 488.4 mm, in 2007 at the highest quarterly precipitation 164 mm (Q3, 2007).

The analysis of leachate water based on the guidelines stated in the Decree of the Minister of Building dated 14 July 2006 on fulfillment of duty by industrial sewage suppliers and principles of sewage supply to sewer systems, showed that permissible PAH concentrations were exceeded (2006).

Concerning the reaction, the analysis of leachate water for 2005-2008 showed an increase from 6.83 in Q1, 2005 to 9.4 pH in Q2, 2008, which confirms a neutral reaction of the examined leachates. Similarly, the results of electrolytic conductivity assessments revealed an increase from 522 $\mu S \cdot cm^{-1}$ in Q1,2006 to 8530 $\mu S \cdot cm^{-1}$ in Q3, 2008. Increased pollution of leachate water was observed for chromium (<0.001 to 0.089 mg $Cr \cdot dm^{-3}$) in quarters 1-4, 2008, particularly in Q3, 2006, mercury (<0.0005 to 0.0014 mg $Hg \cdot dm^{-3}$) in quarters 1, 2005 to 1, 2007 and TOC (78.22 to 250 mg $\cdot dm^{-3}$) during the period from Q1, 2005 to Q3, 2008 and PAH (0.03 to 1.14 mg $\cdot dm^{-3}$) in the quarters 1, 2005 to quarter 2, 2008.

A decreased heavy metal pollution in the studied leachate water was stated on the basis of lead concentration oscillating from 0.08 to <0.01 mg Pb $\cdot dm^{-3}$) from Q2, 2005 to Q2, 2008; cadmium concentration from <0.012 – <0.003 mg Cd $\cdot dm^{-3}$ from Q2, 2005 to Q4, 2008; copper from 0.046 – <0.01 mg $Cu \cdot dm^{-3}$ from Q1, 2006 to Q4, 2008 and zinc from 0.368 – 0.033 mg Zn $\cdot dm^{-3}$ between Q1, 2006 and Q3, 2008.

Analysis of leachate water quality for the years 2005-2008 did not demonstrate the effect of elevated precipitation registered in 2007 on the change of leachate water composition. Average precipitation in the area of the analyzed landfill was much lower than registered on other landfills (Szymańska-Pulikowska A., 2009). The above fact confirms that atmospheric precipitation has small influence on the course of chemical processes occurring on a landfill (Grygorczuk-Petersons E.H., Wiater J., 2012).

The conducted analysis of leachate water quality revealed a change of acid reaction to neutral. According to Szymańska-Pulikowska (2009) such change is characteristic for the acetogenesis period. Increased pollution of leachates was registered on the basis of results of electrolytic conductivity and TOC concentration measurements, heavy metal (Cr and Hg) and PAHs concentrations. The registered over-the-norm increase in PAH concentrations confirmed the presence of organic substances of anthropogenic origin (Szymański K., 1999). Apart from increased pollution in the analyzed leachate water, also a decrease in some microelement content was observed. A downward trend for heavy metals

(Pb, Cd, Cu and Zn) results from the progressing ageing of wastes deposited on the landfill (Szyc J., 2003).

## CONCLUSIONS

- Increased atmospheric precipitation did not affect a change in leachate water composition.
- Composition of the analyzed leachate waters reveals variability on the basis of physicochemical parameters.
- A change of acid reaction to neutral is connected with decomposition of organic substance contained in the leachates
- Elevated PAHs content in leachate water results from the effect of anthropogenic pollution.
- A decrease in heavy metal concentration in leachate waters results from ageing of the deposited wastes.

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Dr. Ing. Grzegorz Przydatek
State Higher School in Nowy Sącz, Poland