Heavy metals in municipal waste dumps leachate and their impact on the environment

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Abstract. The potential impact of the leachate generated by the municipal waste landfills on the environment has become very important in the last few years, as shown by the large number of scientifically work elaborated. Depending on the composition, the degree of decomposition of municipal waste or hydrological factors, the leachate can become extremely contaminated and dangerous for the environment, especially in the case of uncontrolled leachate drainage. Mainly, the contaminants found in the leachate are dissolved organic matter, inorganic macro-components, xenobiotic organic compounds or heavy metals. The importance of heavy metals from the leachate’s composition consists of their risk and toxicity on human health and environment. The current paper presents the analysis of the content of metal ions from the composition of the leachate generated by a non-compliant municipal waste landfill. It also presents a comparative study of the composition of the analysed leachate with the composition of the leachate analysed in other studies. The paper reviews the management of the leachate generated by the non-compliant municipal waste landfill.

Key Words: leachate, heavy metals, drainage, impact, pollution.

Aims and background. The storage of municipal solid waste (MSW) shows an increased interest in the last 10-20 years, especially due to its social and environmental impact, which lead to the development of environmental policies and optimization of the environmental legislation. As an example, the decrease of the quantity of waste generated, the recovery with the purpose of reusing, recycling, composting and incinerating for generating energy at the expense of final waste storage are just a few principles resulted from optimising waste management with the aim of minimising their impact on human health and environment (Abd El-Salam & Abu-Zuid 2015).

Waste landfills can be considered highly heterogeneous or varied environments, due to the composition of stored waste, location, environmental conditions or their age (Nagendra et al 2006).

These aspects turn waste landfills into multidisciplinary objectives which require profound studies to define the individuality of each waste landfill. Historically, waste management was dominated, highlighted and influenced by health problems and the safety of the population (Seadon 2006).

Even though waste storage has economic advantages, allows waste decomposition in controlled conditions and minimises certain risks, there have been some changes in the conception and approach of waste storage in the last few years, generated mostly by the alternative solutions in waste management. Despite all this, even in the present, waste storage is one of the most common practices of municipal solid waste management worldwide, probably because is the simplest and cheapest method (Aljaradin & Persson 2012).

Non-compliant storage leads to the release of toxic substances in the environment, like heavy metals that get into the reserves of groundwater and surface water. These activities are contrary to the sustainability criteria (Adedeji & Olayinca 2014).

The leachate composition is presented in many scientifically papers, therefore there is a general image regarding the physicochemical composition of the leachate generated by the municipal waste landfills. The leachate contains harmful substances like phthalates, polycyclic aromatic hydrocarbons, organic micro-pollutants or heavy metals that can be assimilated by different aquatic species or plants through which they are transferred to the food chain and bio-accumulate in the human body in cases of long exposure. In this case, it is mandatory that the leachate generated by the municipal waste landfills that gets into the surface waters be examined, in order to identify the
potential risks that people who use the polluted water are exposed to (Adewuyi & Opasina 2010).

The common parameters of the most papers are the following: pH, conductivity, total dissolved solids, total suspended solids, chemical oxygen consumption, phosphates, nitrates, sulphates, ammonia or heavy metals like Ni, Fe, Cu, Mn, Cr, Cd, Zn and Pb. Just like the waste dumps, the leachate gains different composition characteristics that depend on numerous environmental factors, such as the age of the landfill, diversity or the percentage of the type of waste stored (Marghade et al 2010; Ayolabi et al 2013).

Other studies demonstrate the influence and the health risks arising from the waste landfills through household water pollution with heavy metals and nitrates (Neamtu et al 2013).

In many countries, passing from non-compliant waste dumps to sanitary or ecological waste dumps, is noticeable. This process is in progress in poor countries. Its importance consists of the actions taken to minimise the impact on the environment but also the modelling of principles and increase of the environment protection standards, establishing a higher level of the future studies in the field. This study aims to analyse the concentration of heavy metals in the leachate generated by municipal household waste dumps.

**Experimental.** The leachate analysed in the present study is generated by the non-compliant municipal waste dump of Huedin municipality. The area was chosen after field visits were conducted, where there was found the lack of a collection system or management of the leachate at the base of the waste dump. Moreover, the drainage of the leachate in the Crisul Repede River accentuated the need to conduct investigations regarding its composition.

The usage of the water in Crisul Repede River by locals for irrigating or for household purposes increases the risks for the population health and for the environment. The impact on environmental factors, especially on groundwater and surface waters is well known. The waste dump is located in the North-Western part of Huedin town, in Cluj County (Figure 1).

![Figure 1. Localization of the municipal waste dump in Huedin town (Quantum GIS 2012).](image)

The geographical coordinates that the dump is located between are 46°52’29.28” North Latitude and 23°0’12.24” East Longitude. The waste dump’s vicinity consists of agricultural lands, pastures and the Crisul Repede River and in the Western part, at a distance of approximately 100 m, there are households. The area of the waste dump has suffered continuous enlargement, up to 1.19 ha in 2009, with a quantity of 171.667 m³
of stored waste. Between 2009 and 2012, a volume of 79.127 m$^3$ of waste was stored. Therefore, it can be concluded that at the end of 2012, the waste dump had an estimated volume of 250.794 m$^3$ and a larger surface. The height of the stored waste layer is 10-12 m (Jascau et al 2015). In 2012, the activity of the waste dump was suspended through the 349/2005 government decision regarding waste storage. Despite this, the surface of the waste dump reaches 3.49 ha in 2014. Figure 2 presents the evolution of the non-compliant municipal waste dump of Huedin town from 2009 to 2014, realised with the Google Earth program.

![Figure 2](image)

Figure 2. The evolution in time of the non-compliant municipal waste dump surface (Google Earth 2009).

The leachate sample prelevation was realised from two points, one located at the base of the waste dump (the leachate’s spring point) and the other located before the confluence of the leachate with the Crisul Repede River (the leachate’s spill point), points represented in Figure 3.

![Figure 3](image)

Figure 3. Sampling points of the leachate in the drain path (Google Earth 2009).
The sampling took place during September 2014. At that time, the air temperature was 20°C and sunny. The leachate samples were collected in sterilised containers and labelled accordingly. The samples were transferred to the laboratory one hour after sampling, all this time being kept at the same temperature as they were taken.

The determination of the metal ions was realised with the help of the flame atomic absorption spectrometer. It was used the Schimadzu AA 6800 atomic absorption spectrometer, considering the specified calibration methodology and SR ISO 11047/1999.

In the process of choosing the sampling points it was taken into account the possibility of determining the evolution of metal ions in the leachate’s composition from the P1-L sampling point to the P2-L sampling point, on the drain path.

Taking into account the age of the dump (working since 1970), it is considered to be an old one, influencing the leachate’s composition as well. There were determined the metal ions of Fe^{2+}, Mn^{2+}, Cu^{2+}, Cr^{3+}, Pb^{2+}, Zn^{2+}, Cd^{2+} and Ni^{2+}.

There were realised comparisons between the results obtained and the results presented in other scientifically papers which analyse the leachate generated by household waste dumps.

**Results and Discussion.** The waste that gets in the waste dump of Huedin town has diverse sources of generation, both from the urban and rural environment, generated in households, societies or different industries, except for the hazardous and industrial waste, but still hazardous waste appears, mixed with the municipal household waste. Certain waste contains heavy metals which are transferred to the leachate by the water that gets in the waste dump. The concentrations of the analysed heavy metals are presented in Table 1, along with the limits of detection (LOD) and the limits of quantification (LOQ) and the concentration limit concerning the concentration of heavy metals ions according to the 352/2005 government decision regarding wastewater discharge in the natural receptors according to the Romanian legislation, with the aim of evaluating and classifying the results obtained.

<table>
<thead>
<tr>
<th>Sample name</th>
<th>Dil. ↓</th>
<th>Fe^{2+}</th>
<th>Mn^{2+}</th>
<th>Cu^{2+}</th>
<th>Cr^{3+}</th>
<th>Pb^{2+}</th>
<th>Zn^{2+}</th>
<th>Cd^{2+}</th>
<th>Ni^{2+}</th>
</tr>
</thead>
<tbody>
<tr>
<td>U.M.</td>
<td>mg L^{-1}</td>
<td>mg L^{-1}</td>
<td>mg L^{-1}</td>
<td>mg L^{-1}</td>
<td>mg L^{-1}</td>
<td>mg L^{-1}</td>
<td>mg L^{-1}</td>
<td>mg L^{-1}</td>
<td>mg L^{-1}</td>
</tr>
<tr>
<td>LOD</td>
<td>0.030</td>
<td>0.015</td>
<td>0.015</td>
<td>0.065</td>
<td>0.130</td>
<td>0.025</td>
<td>0.010</td>
<td>0.060</td>
<td></td>
</tr>
<tr>
<td>LOQ</td>
<td>0.100</td>
<td>0.050</td>
<td>0.050</td>
<td>0.200</td>
<td>0.500</td>
<td>0.050</td>
<td>0.200</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Limit</td>
<td>5</td>
<td>1</td>
<td>0.1</td>
<td>1</td>
<td>0.2</td>
<td>0.5</td>
<td>0.2</td>
<td>0.5</td>
<td></td>
</tr>
<tr>
<td>P1-L</td>
<td>1.00</td>
<td>5.955</td>
<td>3.683</td>
<td>0.990</td>
<td>0.287</td>
<td>&lt;0.130</td>
<td>2.022</td>
<td>&lt;0.010</td>
<td>0.272</td>
</tr>
<tr>
<td>P2-L</td>
<td>1.00</td>
<td>7.417</td>
<td>0.691</td>
<td>0.535</td>
<td>0.277</td>
<td>&lt;0.130</td>
<td>0.671</td>
<td>&lt;0.010</td>
<td>0.223</td>
</tr>
</tbody>
</table>

Generally, the concentrations of heavy metals tend to decrease in the P2-L sampling point compared to the P1-L sampling point. This situation is generated by the phenomenon of precipitation of heavy metals in the culvert of the leachate. In what iron is concerned, it is recorded a significant increase of the concentration in P2-L sampling point, although there are no other sources or tributaries on the field that would influence the iron concentration in the leachate.

In the case of the other metal ions that were analysed, the concentration tends to reduce from the P1-L sampling point to the P2-L sampling point, causing a smaller negative effect for the natural receptor and a bigger negative effect on the soil in which heavy metals are sedimented.

In Figure 4 there is a graphic representation of the concentrations of heavy metals in the analysed leachate samples along with the permitted limits of wastewater discharge in surface waters. The comparison of the results obtained after the analyses were conducted on the leachate with the limits of the concentrations legally established shows significant exceeding of the limit values in the case of Fe^{2+}, Mn^{2+}, Cu^{2+} and Zn^{2+}.
Up next there is presented a comparative study of the metal ions content of the leachate generated by the municipal household waste dump of Huedin town with other municipal waste dumps found in the specialty literature. The data in Table 2 shows that the age of the dump along with the stabilization of the solid waste have a significant effect upon the characteristics of the leachate generated.

The concentrations of heavy metal ions in different countries

<table>
<thead>
<tr>
<th>Age of waste dump</th>
<th>Country</th>
<th>Fe$^{2+}$</th>
<th>Mn$^{2+}$</th>
<th>Cd$^{2+}$</th>
<th>Cu$^{2+}$</th>
<th>Cr$^{3+}$</th>
<th>Pb$^{2+}$</th>
<th>Zn$^{2+}$</th>
<th>Ni$^{2+}$</th>
<th>References</th>
</tr>
</thead>
<tbody>
<tr>
<td>Young</td>
<td>Italy</td>
<td>2.70</td>
<td>0.04</td>
<td>0.02</td>
<td>15.70</td>
<td>2.21</td>
<td>0.03</td>
<td>0.16</td>
<td>0.31</td>
<td>Lopez et al (2004)</td>
</tr>
<tr>
<td>Mature</td>
<td>Canada</td>
<td>1.28-4.90</td>
<td>0.028-0.541</td>
<td>0-0.164</td>
<td>-</td>
<td>-</td>
<td>-</td>
<td>-</td>
<td>-</td>
<td>Renou et al (2008)</td>
</tr>
<tr>
<td>Mature</td>
<td>Hong Kong</td>
<td>3.811</td>
<td>0.182</td>
<td>-</td>
<td>0.12</td>
<td>-</td>
<td>-</td>
<td>-</td>
<td>-</td>
<td>Renou et al (2008)</td>
</tr>
<tr>
<td>Mature</td>
<td>South Korea</td>
<td>76</td>
<td>16.4</td>
<td>-</td>
<td>0.78</td>
<td>-</td>
<td>-</td>
<td>-</td>
<td>-</td>
<td>Renou et al (2008)</td>
</tr>
<tr>
<td>Mature</td>
<td>Spain</td>
<td>7.45</td>
<td>0.17</td>
<td>-</td>
<td>0.26</td>
<td>-</td>
<td>-</td>
<td>-</td>
<td>-</td>
<td>Renou et al (2008)</td>
</tr>
<tr>
<td>Old</td>
<td>Brazil</td>
<td>5.50</td>
<td>0.20</td>
<td>0.01</td>
<td>0.08</td>
<td>0.2</td>
<td>0.1</td>
<td>0.35</td>
<td>0.10</td>
<td>Silva et al (2004)</td>
</tr>
<tr>
<td>Old</td>
<td>France</td>
<td>26</td>
<td>0.16</td>
<td>0.005</td>
<td>0.04</td>
<td>0.015</td>
<td>0.002</td>
<td>0.04</td>
<td>0.31</td>
<td>Tabet et al (2002)</td>
</tr>
<tr>
<td>Old</td>
<td>Malaesia</td>
<td>4.10-19.5</td>
<td>15.5</td>
<td>-</td>
<td>4.60</td>
<td>0.60</td>
<td>-</td>
<td>0.10</td>
<td>-</td>
<td>Aziz et al (2004)</td>
</tr>
<tr>
<td>Old</td>
<td>Romania</td>
<td>5.955</td>
<td>3.683</td>
<td>0.01</td>
<td>0.99</td>
<td>0.287</td>
<td>0.130</td>
<td>2.02</td>
<td>0.272</td>
<td>This study</td>
</tr>
</tbody>
</table>

Also, the relationship between the age of the dump and the composition of the organic matter exposes important criteria for choosing a correct method of treating leachate. It is seen in the case of old waste dumps that they record a higher concentration of heavy metals (Silva et al 2004).

The newer waste landfills have a lower concentration of metal ions in the generated leachate, due to the fraction of stored waste, as nowadays the recycled materials or the ones with recovery potential don’t reach the waste landfills (iron, copper, lead etc.).
**Conclusions.** The surface water’s body in the vicinity of the municipal waste dump represents a natural receptor of the pollution generated by the waste dump through the leachate that reaches the Crisul Repede River.

It is seen during the drainage of the leachate from the P1-L sampling point to the P2-L sampling point a decrease of the concentration of metal ions, except for the iron ions which increase their concentration by 2.5 mg L⁻¹, although on the field there were not identified any other sources that can lead to the increasing of this concentration.

It is highlighted the leachate’s capacity of self-purification, reaching in the P2-L point values that fall within the maximum permitted limit for discharging wastewaters in natural receptors.

Therefore it is found the need to solve immediately the problem regarding the leachate drained in the surface water.

**Acknowledgements.** This paper is supported by the Sectorial Operational Programme Human Resources Development POSDRU/159/1.5/S/137516 financed from the European Social Fund and by the Romanian Government.

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