EVALUATION OF LANDFILL LEACHATE QUALITY WITH BATTERY OF BIOTESTS

Gabriela Kalčíková, Jana Zagorc-Končan, Andreja Žgajnar Gotvajn

Faculty of Chemistry and Chemical Technology, University of Ljubljana, Aškerčeva 5, 1000 Ljubljana, Slovenia, e-mail: g.kalcikova@gmail.com

Abstract: In recent years, there has been intensive interest in ecotoxicity testing due to the fact that chemical analyses alone do not allow evaluation of effects of pollutants on the environment. Ecotoxicity tests integrate the biological effect of all compounds present and thus they are an indispensable approach for evaluation of effect of mixtures of pollutants (e.g. wastewaters, landfill leachates) on the environment. Landfill leachate from regional municipal landfill was used in this study. Leachates prior and after biological treatment were sampled twice and different representative physico-chemical parameters were determined. Leachates from the first sampling were more polluted and more toxic than the leachates from the second sampling. Experiments showed, that the most sensitive organism was Lemna minor and the least sensitive one was Artemia salina. Ecotoxicity tests equivalently accompanied physico-chemical parameters in reliable determination of efficiency of biological treatment plant. Results of ecotoxicity testing were also compared and interspecies correlations were observed as well as correlations between toxicities and concentration of pollutants in landfill leachates were determined. Presented study confirmed that ecotoxicity tests are essential for reliable assessment of environmental impact of landfill leachate. Additionally, they should also take place for more comprehensive assessment of efficiency of landfill leachate treatment plant.

Keywords: battery of biotests, ecotoxicity, landfill leachate, biological treatment plant

INTRODUCTION

Landfill leachates represent a very complex mixture that commonly contains a large number of toxic and persistent pollutants (Öman et al. 1993; Schrab et al. 1992). These pollutants usually occur in very low concentrations, but they can cause many biological effects to aquatic and terrestrial organisms. Many of pollutants from landfill leachate can be identify by chemical analysis, however chemical analysis are not able to reveal the interactions between pollutants in such mixture and their effect to organisms (Öman et al. 1993; Pivato et al. 2005). For that reasons, ecotoxicity tests – bioassays, have become a fundamental tool for assessment of effect of mixture of pollutants (e.g.
landfill leachate) on the environment. Bioassays integrate the effect of all contaminants including synergism, aditivism or antagonism, as well as they can provide valuable information about bioavailability (Wilke et al. 2008).

For reliable assessment of effect of landfill leachate on the environment, ecotoxicity testing use a battery of biotest including organisms from different trophic levels of food chain. They provide an appropriate approach due to the different sensitivity of various species to number of potential toxicants (Isidori et al. 2003). However, it is unfeasible and often unethical to test many species (especially vertebrates) and thus interspecies correlation could be a useful tool for predicting landfill leachate toxicity to one species based on the toxicity of the same leachate to other species (Wang at al. 2002).

The aim of our study was to determined different representative physico-chemical parameters of landfill leachates, to assess ecotoxicity by battery of biotest including bacteria \textit{Vibrio fischeri}, a mixed culture of activated sludge, duckweed \textit{Lemna minor}, white mustard \textit{Sinapis alba} and brine shrimp \textit{Artemia salina}, to compare physico-chemical parameters and toxicity of investigated landfill leachates and to assess possibility of interspecies correlation between chosen organisms.

METHODOLOGY

Landfill leachate used in this study was obtained from regional municipal landfill in Slovenia. Leachates prior and after biological treatment in sequencing batch reactor (SBR) were sampled twice (March 2008 and January 2010) and different physico-chemical parameters as pH, BOD$_5$ (Biochemical Oxygen Demand), COD (Chemical Oxygen Demand), DOC (Dissolved Organic Carbon), concentration of ammonium nitrogen, nitrite nitrogen, nitrate nitrogen, chlorides and phosphates were determined. All applied ISO standard procedures are listed in Žgajnar Gotvajn et al. (2009).

For assessment of landfill leachate toxicity several toxicity test have been used: bioluminescence inhibition test using luminescent bacteria \textit{Vibrio fischeri} (DR. LANGE LUMISTox, 2001) (ISO 11348-2 1997), activated sludge oxygen consumption inhibition test (ISO 8192 2007), \textit{Lemna minor} growth inhibition test (ISO 20079 2005), \textit{Sinapis alba} root growth inhibition test (Fargašová 2004) and acute immobilization test using brine shrimp \textit{Artemia salina} (Persoone et. al. 1984). All results from toxicity testing expressed as EC$_{50}$ values has been converted to Toxic Units (TU) (Bitton 1998).

RESULTS

All four sampled landfill leachates (R1 – raw leachate from the first sampling, T1 – treated leachates from the first sampling, R2 – raw leachate from the first sampling, T2 – treated leachate from the second sampling) were
physico-chemically characterized and toxicity was investigated (tab. 1). There are significant differences between leachates from the first and from the second sampling. Both leachates from the first sampling (R1, T1) were more polluted, more toxic as well as treatment efficiency of existing SBR reactor was low (COD removal reached only 54%). Treated leachate T1 exceed Slovenian effluent limits for BOD₅, COD and concentration of ammonium (Uradni list 2008), while in T2 sample just the concentration of ammonium was too high. However, during the second sampling treatment efficiency of SBR was very good (except ammonium removal) and for some organisms it led even to complete detoxification, which was not the case for R1 and T1. All leachates were the most toxic to *Lemna minor* and *Vibrio fischeri*, both organisms well known by its sensitivity to organic pollution.

**Tab. 1:** Results of physico-chemical characterization and toxicity testing of landfill leachates

<table>
<thead>
<tr>
<th>Physico-chemical parameter</th>
<th>R1</th>
<th>T1</th>
<th>R.E. (%)</th>
<th>R2</th>
<th>T2</th>
<th>R.E. (%)</th>
</tr>
</thead>
<tbody>
<tr>
<td>pH</td>
<td>8.4</td>
<td>7.5</td>
<td>/</td>
<td>7.9</td>
<td>7.5</td>
<td>/</td>
</tr>
<tr>
<td>BOD₅ (mg L⁻¹)</td>
<td>150 ± 9</td>
<td>43 ± 2</td>
<td>71</td>
<td>395 ± 16</td>
<td>27 ± 1</td>
<td>93</td>
</tr>
<tr>
<td>COD (mg L⁻¹)</td>
<td>2455 ± 96</td>
<td>1130 ± 50</td>
<td>54</td>
<td>1800 ± 80</td>
<td>95 ± 4</td>
<td>95</td>
</tr>
<tr>
<td>DOC (mg L⁻¹)</td>
<td>336 ± 4</td>
<td>40 ± 1</td>
<td>88</td>
<td>1680 ± 34</td>
<td>258 ± 3</td>
<td>85</td>
</tr>
<tr>
<td>NH₄⁺ - N (mg L⁻¹)</td>
<td>596 ± 30</td>
<td>160 ± 10</td>
<td>73</td>
<td>399 ± 20</td>
<td>158 ± 10</td>
<td>60</td>
</tr>
<tr>
<td>NO₂⁻ - N (mg L⁻¹)</td>
<td>62 ± 2</td>
<td>160 ± 9</td>
<td>/</td>
<td>2 ± 0.1</td>
<td>11 ± 0.6</td>
<td>/</td>
</tr>
<tr>
<td>NO₃⁻ - N (mg L⁻¹)</td>
<td>172 ± 10</td>
<td>302 ± 12</td>
<td>/</td>
<td>22 ± 1</td>
<td>36 ± 2</td>
<td>/</td>
</tr>
<tr>
<td>Cl⁻ (mg L⁻¹)</td>
<td>1650 ± 60</td>
<td>1000 ± 47</td>
<td>39</td>
<td>1314 ± 66</td>
<td>149 ± 7</td>
<td>89</td>
</tr>
<tr>
<td>PO₄³⁻ - P (mg L⁻¹)</td>
<td>66 ± 4</td>
<td>40 ± 3</td>
<td>39</td>
<td>37 ± 2</td>
<td>2 ± 0.2</td>
<td>94</td>
</tr>
<tr>
<td>Toxicity (TU)</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td><em>Vibrio fischeri</em></td>
<td>12.7 ± 3.2</td>
<td>5.8 ± 1.3</td>
<td>54</td>
<td>4.0 ± 1.0</td>
<td>1.2 ± 0.3</td>
<td>70</td>
</tr>
<tr>
<td>Activated sludge</td>
<td>5.1 ± 1.5</td>
<td>2.9 ± 0.8</td>
<td>43</td>
<td>1.4 ± 0.3</td>
<td>N.T.</td>
<td>100</td>
</tr>
<tr>
<td><em>Lemna minor</em></td>
<td>16.7 ± 1.0</td>
<td>5.5 ± 0.2</td>
<td>67</td>
<td>14.3 ± 0.7</td>
<td>1.0 ± 0.1</td>
<td>93</td>
</tr>
<tr>
<td><em>Sinapis alba</em></td>
<td>10.2 ± 0.5</td>
<td>4.5 ± 0.3</td>
<td>56</td>
<td>4.0 ± 0.3</td>
<td>N.T.</td>
<td>100</td>
</tr>
<tr>
<td><em>Artemia salina</em></td>
<td>6.4 ± 1.2</td>
<td>1.5 ± 0.1</td>
<td>77</td>
<td>1.4 ± 0.3</td>
<td>N.T.</td>
<td>100</td>
</tr>
</tbody>
</table>

R.E. – Removal efficiency in %
N.T. – No toxic effect observed
/ – Not determined
Artemia salina and activated sludge did not show significant sensitivity to any landfill leachate, but it has already been confirmed to be highly tolerant to leachates (Bernard et al. 1997). Activated sludge was also not very sensitive to investigated landfill leachates, and it has been concluded, that low treatment efficiency of biological sequencing batch reactor is not a consequence of toxic impact of leachates, but it is probably due to their low biodegradability (BOD5/COD = 0.06 for R1 and 0.22 for R2). This assumption is also confirmed by higher treatment efficiency at the time of the second sampling, where the influent of SBR (R2) was more biodegradable.

Results of toxicity testing and physico-chemical analyses were compared and correlations between them were assessed. Only the most sensitive organism Lemna minor showed very good correlation between toxicity of the leachates and COD ($r^2 = 0.95$) and between toxicity of leachates and concentration of chlorides ($r^2 = 0.89$). Correlations between toxicity to other organisms and physico-chemical parameters were not appreciable. Interspecies correlations were observed between Vibrio fischeri and Lemna minor ($r^2 = 0.95$), Sinapis alba and Lemna minor ($r^2 = 0.97$) and Sinapis alba and Vibrio fischeri ($r^2 = 0.99$).

**DISCUSSION**

Presented results showed that composition of landfill leachates from the same landfill can be strongly variable. Variability can be caused by different weather conditions, where low temperatures and low amount of rainfall (e.g. January sampling) can preserve the landfill and lower biodegradation rates, while on the other hand increasing temperatures and intensive rainfalls can lead to intensive degradation as well as increasing amount of pollution in the leachate (e.g. March sampling). Treatment efficiency of existing biological treatment plant can also be affected by many factors e.g. increased toxicity of leachate caused inhibition of activity of microorganisms employed for biological treatment. Investigated raw leachates from the first and the second sampling showed higher toxicity to Sinapis alba and Lemna minor and thus the leakage of raw leachate could present a potential risk for plants growing closely to the side. Results of ecotoxicity testing also showed that various organisms respond differently to landfill leachate and therefore the use of battery of biotest is essential for reliable assessment of effect of landfill leachates on the environment. Results also indicated that ecotoxicity tests accompanied by physico-chemical parameters determined prior and after treatment equivalently assess the efficiency of biological treatment plant. When toxicity and physico-chemical parameters are compared, main parameter responsible for toxicity of landfill leachate seems to be COD. Several interspecies correlations were noticed between Vibrio fischeri, Lemna minor and Sinapis alba. They can be a consequence of higher sensitivity of tested organisms to investigated landfill
leachates. However, to obtain precise information about toxicity to one organism based on toxicity to other organism, more results should be compared.

CONCLUSION

Our study showed that ecotoxicity tests can be used for various purposes. Mainly, they are essential for reliable assessment of environmental impact of landfill leachate which can be strongly variable. They can also take place for more comprehensive assessment of efficiency of landfill leachate treatment plant. Some organisms showed a potential to be a good tool for interspecies correlation resulting in avoiding excessive toxicity testing and save a lot of work, time and testing organisms.

REFERENCES


