Organic compounds in re-circulated leachates of aerobic biological treated municipal solid waste

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Abstract
Biodegradation of organic matter is required to reduce the potential of municipal solid waste for producing gaseous emissions and leaching contaminants. Therefore, we studied leachates of an aerobic-treated waste from municipal solids and a sewage sludge mixture that were re-circulated to decrease the concentration of biodegradable organic matter in laboratory-scale reactors. After 12 months, the total organic C and biological and chemical oxygen demands were reduced, indicating the biodegradation of organic compounds in the leachates. Curie-point pyrolysis-gas chromatography/mass spectrometry (Py-GC/MS) and pyrolysis-field ionization mass spectrometry (Py-FIMS) revealed that phenols, alkylaromatic compounds, N-containing compounds and carbohydrates were the predominate compounds in the leachates and solid waste. Leachate re-circulation led to a higher thermal stability of the residual organic matter as indicated by temperature-resolved Py-FIMS. Admixture of sewage sludge to solid waste was less effective in removing organic compounds from the leachates. It resulted in drastic higher and more bio-resistant loads of organic matter in the leachates and revealed increased proportions of alkylaromatic compounds. The biodegradation of organic matter in leachates, re-circulated through municipal solid waste, offers the potential for improved aerobic waste treatments and should be investigated on a larger scale.

Introduction
The harmless removal of municipal solid waste (MSW) requires biodegradation of organic matter to decrease the potential for gas emissions, leaching of organic waste water and other environmental contamination. This can be achieved by a combination of mechanical and biological treatments of MSW under aerobic conditions that stabilize the organic matter remaining in MSW prior to land-filling (Pichler 1999). Addition of sewage sludge can accelerate the stabilization of organic matter due to optimized water-balance and nitrogen supply (Updegraff 1972). Leachates from biologically treated MSW are generally highly loaded with organic matter, and these can be strongly reduced by re-circulation through the decomposing waste (Collins & Spillmann 1977, 1980; Jourdan 1983; Jourdan et al. 1982; Spillmann & Collins 1979). For example, decreases in chemical oxygen demand (COD) from 15000 to 500 mg O₂ l⁻¹ and in biological oxygen demand (BOD) from 5000 to 10 mg O₂ l⁻¹ were reported for a treatment period of 12 months, a time period equivalent to a biological trickling-filter (Collins & Spillmann 1977). Some authors speculated that enrichment of a refractory organic substance was the reason for decreases in bio-degradability of organic matter in leachates (Jourdan 1983; Stegmann & Knoch 1975). The same was described for organic matter of anaerobic
landfill leachates (Göbbels & Püttermann 1997; Harmsen 1983; Kettern 1990). These authors suggested that the decreased biodegradability of the organic matter was induced by polymerization reactions of non-biodegradable organic matter.

Infrared spectroscopy indicated carbohydrates, peptides, lipids and lignin compounds in leachates (Artiola-Fortuny & Fuller 1982). Curie-point pyrolysis-gas chromatography/mass spectrometry (Cp Py-GC/MS) of non-biodegradable organic matter fractions from leachates showed predominant signals of phenols, aromatics and N-containing compounds (Göbbels & Püttermann 1997). Similarly, gas chromatography/mass spectrometry (GC/MS) of solvent-extracted organic matter from leachates revealed the most prominent signals for phenols, alkylaromatics and a variety of N-containing compounds (Öman & Hynning 1993; Paxéus 2000; Schultz & Kjeldsen 1986). However, all these mass spectrometric investigations were carried out on leachates from anaerobic landfills.

To the best of our knowledge, leachates from aerobic waste treatments and re-circulated leachates have not yet been investigated by modern analytical methods. Therefore, the objectives of the present study were:

(1) to evaluate the composition and changes of organic matter in re-circulated leachates during a long-term aerobic biological waste treatment using two independent mass-spectrometric methods,

(2) to elucidate which organic substances were preferentially eluted from the decomposing MSW, and which changes in composition and stability the remaining organic matter underwent, and

(3) to investigate effects of sewage sludge addition on the total content and composition of organic matter in re-circulated leachates and in the solid waste.

We hypothesize that the re-circulation of leachate through the MSW leads to biodegradation of easily decomposable organic matter and a biological stabilization of recalcitrant organic matter that remains in the leachate and the leached solid waste.

Materials and methods

Aerobic biological waste treatment

Leachate re-circulation through a MSW and a mixture of MSW with sewage sludge were investigated in laboratory-scale reactors under aerobic conditions. The glass column-reactors had a diameter of 0.3 m and a height of 1.5 m and were filled each with 40 kg of waste and a waste+sewage sludge-mixture (ratio 4:1 by weight), respectively. The used sewage sludge was neither anaerobically nor aerobically stabilized, but mechanically dehydrated and conditioned with lime. The reactors were aerated by an oil-free compressor from the bottom of the columns (Degener et al. 2004). To simulate an aerobic biological MSW treatment under field conditions in the laboratory-scale reactors, computational temperature-controlled water jackets were used for the maintenance of the biological processes. The leachates collected at the ground of the columns were re-circulated permanently to the top of the columns by a peristaltic pump.

Samples, sample preparation and chemical analyses

The treatment periods and sample-codes are shown in Table 1. Samples of the leachates of both reactors were taken at their first output after 6 months from the start (L1-MSW and L1-MSW + SS) and after 12 months at the end of the waste treatment process (L2-MSW and L2-MSW + SS). Due to thermophilic conditions prior to the first leachate

<table>
<thead>
<tr>
<th>Treatment-period (months)</th>
<th>Sample-code</th>
<th>Solid waste</th>
</tr>
</thead>
<tbody>
<tr>
<td>Leachate</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Municipal solid waste</td>
<td>6</td>
<td>L1-MSW</td>
</tr>
<tr>
<td></td>
<td>12</td>
<td>L2-MSW</td>
</tr>
<tr>
<td>Municipal solid waste + sewage sludge mixture</td>
<td>6</td>
<td>L1-MSW + SS</td>
</tr>
<tr>
<td></td>
<td>12</td>
<td>L2-MSW + SS</td>
</tr>
</tbody>
</table>

Table 1. Sample-codes of the analyzed leachates and solid waste