The role of metals in methane production from shredder waste in landfills

Ehsan Fathi Aghdam
Charlotte Scheutz
Peter Kjeldsen

ATHENS2017 conference
Introduction

- Source separated iron and metal containing waste products including bicycles, prams, vehicles, white goods, etc.
- Mechanical treatment (shredding and magnetic separation)
- The residue: shredder waste
- Metals, plastic, rubber, wood and foam.

- Significant production of landfill gas at shredder waste (SW) monofills (Mønster et al., 2015; Olsen and Willumsen, 2013; Scheutz et al., 2011)

- Unusual composition
  high methane content and very low content of carbon dioxide (Olsen and Willumsen, 2013; Scheutz et al., 2011)
Hypothesis

- In anaerobic digestion process 30% of $CH_4$ is produced by:

$$4H_2 + CO_2 \rightarrow CH_4 + 2H_2O$$

- $H_2$ by anaerobic corrosion of different metals in shredder waste

$$Fe^0 \rightarrow Fe^{2+} + 2e^-$$
$$2H_2O \rightarrow 2H^+ + 2OH^-$$
$$Fe^0 + 2H_2O \rightarrow Fe(OH)_2 + H_2$$

Objectives:

- The objective of this study was to investigate the role of metals contained in SW in $CH_4$ production from SW.
Site description
Sampling and preparation of samples

- According to the year of deposition
  - 2009 (SW2009)
  - 2012 (SW2012)
  - Fresh SW (FSW)

- Long-pile principle:
  - Subdivided three time
Sampling and preparation of samples

In the lab:
- Long-pile principle:
  - Subdivided three time

- Combined (COM):
  SW2009+SW2012+FSW based on equal wet weight
Sampling and preparation of samples

- Metals, wires and stones were separated
- cutter mill with 1 mm sieve

Characterization
- Total solids (TS)
- Volatile solids (VS)
- Total carbon (TC)
- Total organic carbon (TOC)
# Biocorrosion experiment

Table 1. Overview of materials used in the biocorrosion experiment.

<table>
<thead>
<tr>
<th>Experimental step</th>
<th>Reactor name</th>
<th>Metals (g)</th>
<th>Inoculum (mL)</th>
<th>Water (mL)</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Step 1: $H_2$ generation by biocorrosion</strong></td>
<td>Water+Fe</td>
<td>2.5</td>
<td>0</td>
<td>0</td>
</tr>
<tr>
<td></td>
<td>Water+Al</td>
<td>0</td>
<td>2.5</td>
<td>0</td>
</tr>
<tr>
<td></td>
<td>Water+Zn</td>
<td>0</td>
<td>0</td>
<td>2.5</td>
</tr>
<tr>
<td></td>
<td>Water+Cu</td>
<td>0</td>
<td>0</td>
<td>0</td>
</tr>
<tr>
<td><strong>Step 2: Impact of metal addition on $CH_4$ yield</strong></td>
<td>Blank</td>
<td>0</td>
<td>0</td>
<td>0</td>
</tr>
<tr>
<td></td>
<td>Inoc+Fe</td>
<td>2.5</td>
<td>0</td>
<td>0</td>
</tr>
<tr>
<td></td>
<td>Inoc+Al</td>
<td>0</td>
<td>2.5</td>
<td>0</td>
</tr>
<tr>
<td></td>
<td>Inoc+Zn</td>
<td>0</td>
<td>0</td>
<td>2.5</td>
</tr>
<tr>
<td></td>
<td>Inoc+Cu</td>
<td>0</td>
<td>0</td>
<td>0</td>
</tr>
</tbody>
</table>
Batch incubation experiment

- 5 L bottles
- Substrates:
  - COM
  - COM+Fe
  - COM+Al
  - COM+Zn
  - COM+Cu
  - STE_COM
  - STE_COM+Fe
  - STE_COM+Al
  - STE_COM+Zn
  - STE_COM+Cu
- Temperature: 37 ºC
- Inoculum: 30 % of the samples wet weight
- Moisture: 75%
- Bottles containing only inoculum and water
# Results and discussion

## Waste characterization

Table 2. Characteristics of different fractions of SW. Numbers in brackets give the standard deviation.

<table>
<thead>
<tr>
<th></th>
<th>TS (%, kg/kg wet waste)</th>
<th>VS (%, kg/kg wet waste)</th>
<th>TC (%, kg/kg dry waste)</th>
<th>TOC (%, kg/kg dry waste)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Shredder waste</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>SW deposited in 2009 (SW2009)</td>
<td>89 (6.54)</td>
<td>18 (1.17)</td>
<td>14 (0.67)</td>
<td>11 (0.93)</td>
</tr>
<tr>
<td>SW deposited in 2012 (SW2012)</td>
<td>83 (1.48)</td>
<td>20 (0.35)</td>
<td>15 (0.82)</td>
<td>14 (0.57)</td>
</tr>
<tr>
<td>Fresh sample (FSW)</td>
<td>91 (0.02)</td>
<td>32 (1.15)</td>
<td>24 (1.99)</td>
<td>21 (1.29)</td>
</tr>
<tr>
<td>Composite SW sample (COM)</td>
<td>82 (0.71)</td>
<td>24 (0.92)</td>
<td>18 (1.24)</td>
<td>16 (0.60)</td>
</tr>
</tbody>
</table>

- FSW > COM > SW2012 > SW2009
Results and discussion

Biocorrosion experiment

- Fe, Al and Zn hydrogen production and enhancement of AD
- Cu inhibition
Results and discussion
Batch incubation experiment

- No abiotic reaction
- Al and Zn: enhancement
- Fe and Cu: inhibition
Results and discussion
Batch incubation experiment

Table 3. CH$_4$ and CO$_2$ concentrations in the headspace of the biotic reactors measured on the last day of the experiment (day 148).

<table>
<thead>
<tr>
<th>Reactor name</th>
<th>CH$_4$ (%)</th>
<th>CO$_2$ (%)</th>
<th>CH$_4$/CO$_2$</th>
</tr>
</thead>
<tbody>
<tr>
<td>COM</td>
<td>50.4</td>
<td>4.0</td>
<td>12.6</td>
</tr>
<tr>
<td>COM+Fe</td>
<td>44.5</td>
<td>3.6</td>
<td>12.4</td>
</tr>
<tr>
<td>COM+Al</td>
<td>53.3</td>
<td>3.2</td>
<td>16.5</td>
</tr>
<tr>
<td>COM+Zn</td>
<td>52.9</td>
<td>1.7</td>
<td>30.7</td>
</tr>
<tr>
<td>COM+Cu</td>
<td>44.7</td>
<td>3.8</td>
<td>11.7</td>
</tr>
</tbody>
</table>

- COM+Al and COM+Zn: higher CH$_4$ and lower CO$_2$ and in comparison to COM reactor.
Conclusions

- No abiotic production of methane
- Zn and Al contribute to high methane production of SW at landfills by producing H2
Thanks for your attention 😊