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

Fathi Aghdam, Ehsan; Scheutz, Charlotte; Kjeldsen, Peter

Publication date:
2017

Document Version
Publisher's PDF, also known as Version of record

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

E. Fathi Aghdam[1], C. Scheutz[1] and P. Kjeldsen[1]

[1] Department of Environmental Engineering, Technical University of Denmark, 2800 Kgs. Lyngby, Denmark
Keywords: anaerobic digestion, biocorrosion, elemental metals, anaerobic batch incubation.
Presenting author email: ehag@env.dtu.dk

Shredder waste (SW) is the waste produced after mechanical treatment of iron and metal containing wastes including vehicles, bicycles, and white goods. SW consists of mainly plastic, metals, rubber, textile, foam, glass and wood. Relatively high production of methane (CH_4) has been observed at SW monofills (Mønster et al., 2015; Scheutz et al., 2011). This is surprising as SW usually contains low fractions of biodegradable waste and the biodegradable fractions have a high content of lignocellulosic components such as wood and cardboard. The reason for high CH_4 production from SW is unknown. Moreover, previous studies have shown gas compositions in SW, which differed from conventional landfill gas—a high CH_4 content and very low or no CO_2 (Olsen and Willumsen, 2013; Scheutz et al., 2011). The reason for the unusual gas composition is also unknown.

Although SW has passed through metal-separation technologies, it still contains metals. We hypothesized that high CH_4 production from SW and unusual gas composition could be due to H_2 production by biocorrosion of metals in the waste, supporting hydrogenotrophic methanogens to convert CO_2 to CH_4, resulting in higher CH_4 content and lower CO_2. The objective of this study was to investigate the role of metals contained in SW in CH_4 production from SW.

SW samples were collected from Odense Nord landfill located in Funen, Denmark. SW samples were taken by an excavator according to the year of deposition: 2009 and 2012. Fresh samples of SW (year 2015) were obtained by sampling the waste on the same day as it was deposited in the waste cell. Samples from 2009, 2012 and fresh sample were mixed together based on equal wet weight to make one composite sample (COM), representative of the whole landfill. Two sets of experiments were performed: biocorrosion experiment and batch incubation experiment.

Biocorrosion experiments were conducted to investigate hypothesis of CH_4 yield enhancement by H_2 production from biocorrosion of metals. According to the conducted literature review Fe, Al, Zn and Cu are the main metals in SW and thus were examined for their ability to produce H_2. The experiment had two steps and both were carried out in duplicate in 1 L glass bottles for 20 days in a 37 ºC incubator. In the first step, H_2 production from elemental metals in contact with water was investigated. In this step, 2.5 g of elemental metals was placed in each incubation bottle and 250 mL of tap water was added to each. In step two, the CH_4 production enhancement of inoculum by addition of metals was investigated. In this step, incubation bottles contained 2.5 g of elemental metals and 250 g of inoculum, resulting a concentration of 10 g/L of liquid for each metal. Bottles containing only inoculum were used as blank to calculate CH_4 production from inoculum alone. Bottles were flushed with N_2 for 15 minutes to establish an anaerobic condition, and then sealed with rubber septum.

Batch incubation experiments were performed in glass bottles with total volumes of 5 L at 37 °C. In order to investigate the role of metals on the CH_4 production, Fe, Al, Zn, and Cu with dimension of 5 mm × 5 mm and concentrations of 5, 2, 2, and 2 % of the substrate wet weight (25, 10, 10, 10 g/L of liquid), respectively, were added separately to the incubation bottles containing the COM samples. Moisture content of the samples was adjusted to 75 % w/w, and inoculum (30 % of substrate wet weight) was added to the incubation bottles. One bottle containing only inoculum and water were used as blank to determine CH_4 production from the inoculum alone, which was subtracted from the CH_4 production of waste samples. Abiotic control experiments were also performed by sterilizing samples (autoclaving three times for 1 h at 121 ºC) to measure possible CH_4 production due to non-microbial processes. All reactors were flushed for 20 minutes with nitrogen gas to make an anaerobic condition.

The first step of biocorrosion experiment showed that H_2 can be produced by Fe, Al, and Zn, but not by Cu. The second step of biocorrosion experiments results showed that adding Fe, Al and Zn to inoculum resulted in higher CH_4 generation than inoculum alone. However, addition of Cu to inoculum resulted in lower CH_4 production in comparison to inoculum alone.

Figure 1 shows cumulative CH_4 production curves of all waste samples during 148 days incubation time. As it can be seen from Figure 1 sterilized reactors did not produce CH_4, indicating there was no abiotic production of CH_4 from SW. Addition of Al and Zn to the COM samples resulted in higher CH_4 production compared to experiments with COM alone, while the addition of Fe and Cu resulted in lower CH_4 production. The obtained result for the impact of Al, Zn and Cu on CH_4 production is in line with the biocorrosion experiment. However, adding Fe resulted in lower CH_4 production in this experiment, while it resulted in higher CH_4 production in the biocorrosion experiment. This could be due to a higher concentration of Fe in this experiment (25 g/L) compared to the biocorrosion experiment (10 g/L). When comparing the headspace CO_2 concentrations of COM reactor with COM+Al and COM+Zn reactors, it was observed that COM+Al and COM+Zn reactors have lower headspace CO_2 and higher CH_4 concentrations. This could be due to utilization of produced H_2 by corrosion of Al and Zn and existing CO_2 in produced biogas by methanogens, resulting in higher CH_4 and lower CO_2 in the headspace of these reactors.

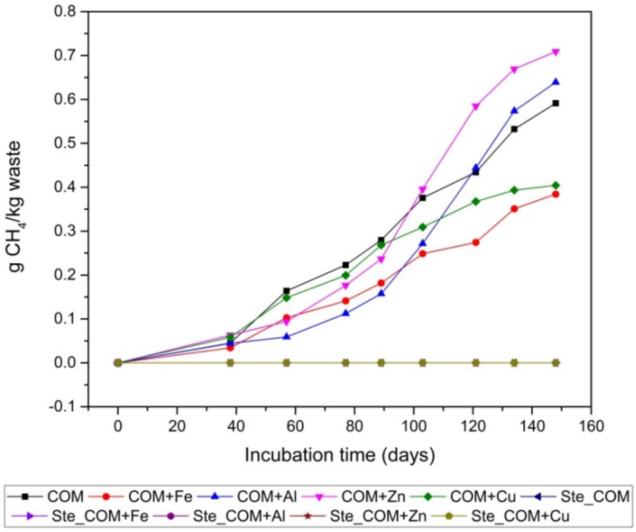

Figure 1. Cumulative CH_4 generation from SW, during period of 148 days. Please note that CH_4 production from sterilized reactors (starting with "Ste") were all zero and thus the curves are on top of each other and not visible on the graph.

In conclusion, it was evident from the incubation experiments that CH_4 production from SW was not abiotic. Al and Zn were found to produce H_2, and it was observed that the produced H_2 can be consumed by methanogens to convert CO_2 to CH_4. Moreover, results of the incubation experiments indicated that the unusual gas composition (higher CH_4 and lower CO_2), and the relatively high CH_4 production rate from landfilling of SW is most likely due to the consumption of existing CO_2 in the produced biogas and H_2 produced by biocorrosion of Al and Zn by methanogens.

References:

Mønster, J., Samuelsson, J., Kjeldsen, P., Scheutz, C., 2015. Quantification of methane emissions from 15 Danish landfills using the mobile tracer dispersion method. Waste Manag. 35, 177–186. doi:10.1016/j.wasman.2014.09.006

Olsen, R., Willumsen, H.C., 2013. Characterization of Gas , Heat and Humidity Profiles in Landfilled Shredder Residue At Odense Nord Landfill , Denmark. Sardinia 2013, Proc. Fourteenth Int. Waste Manag. Landfill Symp. 30 Sept. 4 October, Sardinia, Italy.

Scheutz, C., Fredenslund, A.M., Nedenskov, J., Samuelsson, J., Kjeldsen, P., 2011. Gas production, composition and emission at a modern disposal site receiving waste with a low-organic content. Waste Manag. 31, 946–955. doi:10.1016/j.wasman.2010.10.021