Anaerobic digestion of road-side-green-cuttings as a potential phytoremediator with different lead concentrations

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Abstract

The utilization of roadside-green-cuttings (grass) for anaerobic digestion increases provides an additional possible source of organic waste for use as a renewable energy source. Grass can be used as a substrate to increase biogas yield. Nevertheless, the anaerobic digestion of this kind of waste can be limited due to the fact that it could be contaminated with heavy metals, in particular from traffic emissions and industrial activity. For this reason the biogas production of grass from a busy road was assessed. Samples of roadside-grass were washed with an organosulphide, which is used for the removal of heavy metals from wastewater. A comparison of the anaerobic digestion of washed and unwashed roadside grass was performed. Results showed that the anaerobic digestion of the unwashed grass was much more effective than the washed grass. A second experiment was carried out and co-fermentation of manure and farm-grass was prepared for anaerobic digestion. Lead was added in the concentrations 500, 1000 and 2000 mg Pb^{2+}/kg. The results showed that the higher the lead concentration, the lower the inhibition of the biogas yield. The grass could be acting as phytoremediator for high lead concentrations. The grass could contain organic compounds, which can assimilate heavy metals.

1 Introduction

The production of biogas from organic waste, like roadside-green-cuttings, is being limited, when heavy metals contents are in high levels. Some studies have confirmed a high concentration of heavy metals i.e. lead (Pb), cadmium (Cd), copper (Cu), nickel (Ni) or zinc (Zn), in soils, grass and roadside-green-cuttings (Olajire & Ayodele 1997, Falahi-Ardakani 1984, Kos et al. 1996). The sources of contamination could be mining, metal factories as well as traffic emissions (Maiz et al. 2000). Contamination levels from automobiles depends on different factors, like traffic volume, distance from the road, depth on the soil profile, wind direction and speed, or vehicle year and driving velocity (Falahi-Ardakani 1984).

In year 1970 Motto et al. found an increase in lead content, from 6.4 to 36.4 ppm, with a traffic increase from 11.000 to 32.000 cars per 12 hours.

According to the federal statistics office of Germany, the roadside-green-cuttings, which were collected besides rivers or railroads, show a high contamination level (Umweltbundesamt 2011). It was shown in a study in the same land that 5.2 % of the studied roadside-green-cuttings had high levels of chromium, copper, lead and platinum (Seling & Fischer 2003). The average gathered roadside-green-cuttings in Germany were published in year 2009 by the Federal Statistics Office. About 4.100 tons of these kinds of waste, from a total of 13.200, were collected from public gardens and parks (Umweltbundesamt 2011).

Schattauer & Weiland (2006) reported a much higher biogas yield of 550-680 m^3/tons VS with roadside-green-cuttings, in comparison to the biogas yield of cattle or pig manure (200-500 m^3/tons VS and 300-700 m^3/tons VS). It is important to remark, that the anaerobic digestion of roadside-green-cuttings can only reach these values, when the cuttings have low lignin content (i.e. grass). In this paperwork the results of the evaluation of roadside-grass as a substrate for the anaerobic digestion are shown.

2 Materials and Methods

2.1 Inoculum and substrate

Manure was used as inoculum and was collected from a biogas plant near Cologne. Samples of road-grass (substrate) were washed with an organosulphid (trimercapto-s-triazin), which is used for the removal of heavy metals from wastewater (EVONIK Industries 2011).

The grass was collected from a busy road in Cologne, Germany. Anaerobic digestion of washed and unwashed road-grass was compared. The anaerobic digestion of all samples was performed in triplicate.

2.2 Toxicity test

Farm-grass was collected near Cologne, where no contamination exposure can be found.

Lead was added in the concentrations 500, 1.000 and 2.000 mg Pb^{2+}/kg in the form of lead oxide. Samples without lead were carried out for control.

2.3 Analytical methods

Biogas and methane production were assessed in batch fermentation tests according to VDI 4630. The daily production of biogas was determined through measurement of the water displaced from a 500 ml conical flask used for gas collection.

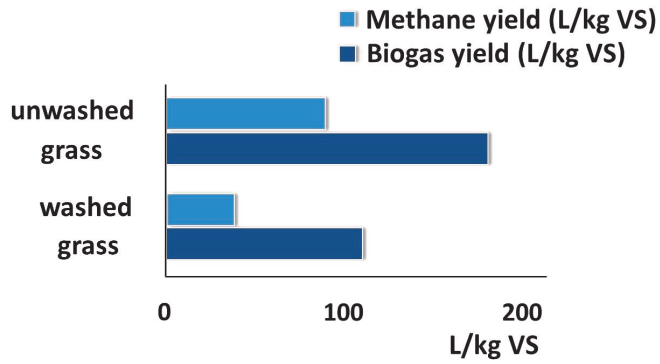
The methane content was measured with a gas analyser, GA94 from Geotechnical Instruments Ltd. The experiments were terminated, when the daily biogas rate was only 1 % of the total volume of produced biogas.

Cadmium, lead and copper content were measured before and after the grass was washed. The heavy metals were extracted with nitric acid and analysed by polarography using the Metrohm 797 VA Computrace.

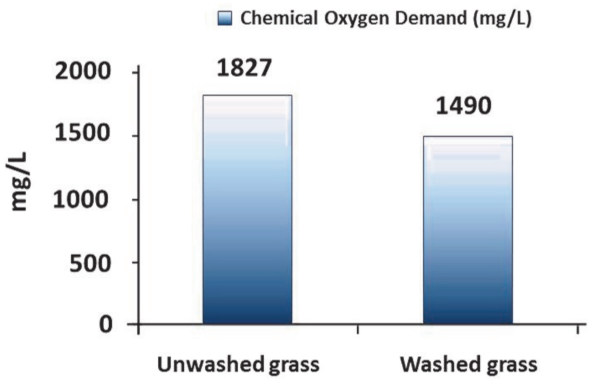
The Chemical Oxygen Demand (COD) was measured with cuvette tests LCK 514 from Hach Lange, which are validated through the ISO 8466-1 and the DIN 38402 A51.

3 Results and discussion

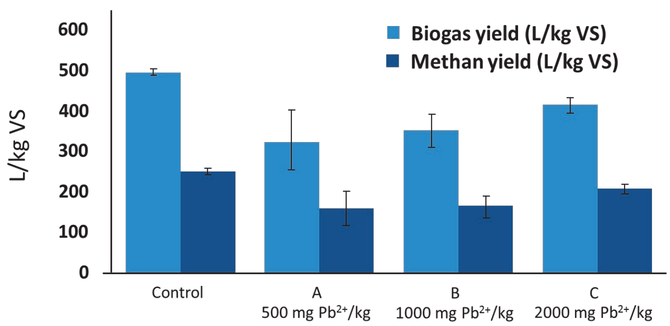
It was expected that heavy metal content in unwashed grass would be so high, that the anaerobic digestion of this grass would be inhibited. However the biogas production of the unwashed grass was much more effective, than the one of the washed grass (see Graphic 1).
The chemical oxygen demand (COD) of both grasses were compared. Results can be seen in the graphic 2. Washed grass showed 20 % less organic content (1490 mg/L) than unwashed grass (1827 mg/L); COD could had been inerted through the organosulphid. Cadmium and lead were 100 % removed, while copper 30 % (see Table 1).
The results of the inhibition of biogas and methane yield through lead showed that the higher the lead concentration, the lower the inhibition of the biogas and methane yield (see Graphic 3).
The grass could be acting as phytoremediator for high lead concentrations. Grass has a leaching potential, it contains organic compounds, which can assimilate heavy metals (Chen et al. 2004).



Graphic 1: Methane and biogas yield of anaerobic digestion of manure with washed and unwashed grass.



Graphic 2: COD in mg/L of unwashed and washed grass.



Graphic 3: Methane and biogas yield with three different lead concentrations (A, B and C).

4 Conclusions

The activity of the anaerobic bacteria was affected by the removal of heavy metals, due to the fact that the minimum required concentration of trace elements, i.e. heavy metals, was reduced. Similarly, the organic content of the substrate was diminished. Chu et al. (2011) found better biogas efficiency from plants which had absorbed a certain concentration of heavy metals through phytoremediation, compared to plants with lower heavy metal contents.
In relation to the inhibition through lead, the grass could be acting as phytoremediator for high lead concentrations. Grass has a leaching potential, it contains organic compounds, which can assimilate heavy metals (Chen et al. 2004, Leidmann et al. 1994).

Table 1: Cadmium (Cd), lead (Pb) and copper (Cu) content in µg/g on washed and unwashed grass.

	Unwashed grass	Washed grass
Cd (µg/g)	4.5	0.0
Pb (µg/g)	4.7	0.0
Cu (µg/g)	38	27.1

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