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Assessment of the aerobic preparation and bottom ash addition as pretreatment steps before landfilling: Impact on methanogenesis kinetics and leachate parameters

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ABSTRACT

This work focuses on assessing the impact of two types of waste pretreatment: addition of bottom ashes and aerobic pretreatment on both the onset and kinetics of methanogenesis and the evolution of different parameters in the leachate. It also studies the correlation between methane production and the different parameters measured in the leachate produced. A total of six 68-L pilots were thus used with fresh municipal solid waste (MSW) shredded to a 40-mm size. After 14 months of landfilling, the control has produced less than 10 NL kg^{-1} DM, which corresponds to around 7% of its biochemical methane potential (BMP). Nevertheless, on one hand for aerobically pretreated waste, the lag phase before the onset of methanogenesis is significantly reduced to 0.9 month compared to more than 1 year for the control. In addition to that, on average 110 NL kg^{-1} DM (90% of the BMP) is produced within around 6.5 months. On the other hand, the waste with added bottom ash shows a slight improvement of the lag phase over the control for one of the duplicate: 6.1 months of lag phase. At this stage, on average of 26 NL kg^{-1} DM waste are detected (22% of the BMP) no final conclusion concerning the impact of bottom ashes could be made. The data obtained for the leachate parameters agrees with the observations on methane production. Statistical correlation study shows that the two components of the corrected PCA interpret 76% of the variability of the data: SUVA (specific UV absorbance at 254 nm) and HPI* (% of hydrophilic compounds) are identified as interesting parameters for following up the biodegradation in landfill conditions.

1. Introduction

According to the French legislation (Arrêté ministériel du 09/09/1997), monitoring and treatment of both leachate and biogas produced in the landfill are obligatory during site operation and extend for an aftercare period of at least 30 years. This legislation joins, at the European level, the council directive 99/31/EC which also aims at preventing or reducing as far as possible the negative impacts on the environment from landfilling through the introduction of stringent technical requirements such as waste treatment. And more recently the European Directive 2008/99/CE promotes the increase in the waste material recovery rate. Unfortunately despite all these challenges, municipal solid waste (MSW) landfilling remains one of the most common waste treatment processes in France. Published data of the French environmental agency (ADEME) show that, in 2006, 48 million tons of MSW were produced with almost 50% diverted to landfills. It is also the case in Italy where even with the high rate of selective collection, 40% of the waste goes to the non-differentiated MSW fraction with an organic content varying between 20% and 25% (Di Maria et al., 2010). In China, 80% of the generated MSW is landfilled (Yue et al., 2011). In this latter case, the organic fraction is predominant and leads most of the times to an acidification in the landfill and consequently longer lag phases before methanogenesis and longer periods for the waste (Shao et al., 2005). In summary worldwide important amounts of organic matter still go to the landfill with important methane and other green house gas emissions potentials.

In Europe and more specifically in Austria and Germany, the mechanical biological treatment (MBT) has been widely used in order to stabilize the waste before landfilling. Biostabilization processes of 2–6 months have been set up keeping in mind that according to De Gioannis et al. (2009) between 80% and 91% reduction of biogas potential can be achieved after 8 and 15 weeks of pretreatment respectively. However, in the European Directive 2001/77/CE, which promotes the increase in the contribution of renewable energy sources to electricity production, the biogas produced by the degradation of waste in the landfills is cited as a source of

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renewable energy. Within this new context of increasing environmental concern and promoting renewable energies, it becomes essential to invest in the optimization of current practices of conventional landfilling and thus modify the approach to the MBT. Waste pretreatment becomes again one key factor with high potential. An interesting consequence has thus been the shift towards a new MBT concept in Italy which reduces the biostabilization period to 2–4 weeks only (Scaglia et al., 2011). Even for the bioreactor landfill, also in Italy, waste pretreatment is looked at to reduce operational problems on site and increase the biogas production (Di Maria and Valentini, 2011). In China, waste pretreatment is also being approached as the solution to limit acidogenesis and thus shorten the lag phase in the landfill (Yue et al., 2011).

In this perspective this work, part of the project BIOPTIME (ANR Precodd 2006) funded by the French National Agency on Research, focuses on studying two types of pretreatments before landfilling: addition of bottom ashes and aerobic pretreatment.

On one hand, bottom ashes are the heterogeneous solid residues remaining after municipal solid waste (MSW) incineration. According to the French Environment and Energy Management Agency (ADEME), 21% were co-disposed with MSW in landfills in 2002, which represent more than 500,000 tons of these residues. In addition to the fact that important amounts of bottom ashes are available, mixing those particles with the waste is expected to generate buffering capacity in the medium due to the alkalinity of the bottom ashes. This latter can positively impact the enzymatic activity of the microorganisms (Lo et al., 2009) thus accelerating the process of biodegradation (Wang et al., 2009). In addition to that, the hydrolysis of polymers contained in the waste results in the production of volatile fatty acids that may cause a drop in the pH (Siegert and Banks, 2005; Wang et al., 2009). Generally, the consumption of VFA by methanogenic microorganisms counterbalances this accumulation but if the rate of hydrolysis is too strong, the pH may drop, inhibiting the overall degradation process. The alkalinity brought by the bottom ashes may therefore counterbalance the acidity generated during the initial fermentation stage and thus accelerate the overall degradation process (Johnson and Furrer, 2002; Guimaraes et al., 2006; Polettini et al., 2007).

On the other hand, Johansen and Bakke (2006) mentioned that even the injection of small amounts of air allows an increase in the hydrolysis rate of waste due to the aerobic activity of the microorganisms. Therefore, the major target of the aerobic pretreatment is the initiation of the hydrolysis that could be a limiting kinetic step for this type of waste. Literature data shows that lignocellulosic compounds, highly abundant in waste, are not easily degradable by microorganisms (Jash and Ghosh, 1996; Ress et al., 1998). The aerobic pretreatment aims thus at initiating the degradation of those types of compounds. Enzymes produced by aerobic fungi can attack the cellulose fibers and allow a better colonization and by that a better degradation of the waste when this latter is placed under anaerobic conditions.

Taking in account these advantages, this work studies the effect of each pretreatment on the onset and kinetics of methanogenesis and the leachate quality. It focuses also on the correlation between methane production and the different parameters measured in the leachate produced in order to find adequate follow-up parameters of the methanogenesis.

2. Materials and methods

2.1. Experimental setup

The pilots used in this study are cylindrical units made up of opaque polyvinyl chloride (PVC) (Fig. 1). They are all air tight with a total working volume of 68 L (H = 63 cm and D = 37 cm). The leachate collection system for the pilots is made up of an inclined bottom and a stainless steel perforated plate which allows the downward flow of the leachate from the waste (Fig. 1). At the lowest point of the leachate reservoir, a valve allows the easy collection of the leachate.

The cover of each pilot is equipped with five valves: a pressure control valve, a valve connecting the inner atmosphere to a micro-gas chromatograph (Varian CP-4900), a valve connected to a drum-type gas meter (Ritter model TG1), a 3-way valve that allows injecting liquid into the system without any gas entry and finally a security valve.

During the experiments, the pilots are placed in a room at 35 °C. The inner atmosphere of each pilot is constantly kept in slight overpressure. The pressure control valve of every pilot is connected to an automatic system that whenever the pressure builds up in the system and reaches 0.3 bar, the pressure opens till the pressure drops to 0.1 bar.

In this study the used feedstock is a fresh MSW obtained from an industrial municipal solid waste treatment plant, where it is crushed with an industrial mill and then screened to obtain the fraction under 40 mm. After this pretreatment, the waste is sent on the same day from the industrial plant and placed directly in the 68-L pilots or sent for aerobic pretreatment. On average, 14.2 ± 0.8 kg of dry matter (DM) were placed in each pilot with almost 50% moisture content. The initial VSs (volatile solids) content was measured at 52 ± 5% of TS (total solids). Its average biochemical methane potential (BMP) was measured at 140 NL CH_4/kg dry matter (DM) of waste. For all samples, the BMP was determined on dried and grinded samples. All tests were performed in 0.5 L serums bottles, in mesophilic conditions and with a substrate/inoculum ratio ranging from 0.2 to 0.5 g of $VS_{substrate}$ per gram of $VS_{inoculum}$. The cumulated biogas production was measured during 44 days and analyzed by micro-gas chromatography. The tests were carried out in duplicate. More details about the method are available in Angelidaki et al. (2009) and Hansen et al. (2004).

In addition to that, Table 1 presents the general composition of the MSW according to the guidelines of the national household characterization survey conducted in 1993 (ADEME, 1995).

Previous experiments (data not published) have shown that when the waste is placed in the pilots even at 50% humidity, the onset of methanogenesis did not occur for a control even after 1 year of landfilling. It was therefore decided to saturate the waste at its placement in the pilot with a leachate collected from a landfill operated by Veolia Environnement in the Ile de France region (78). Over 30 L of fresh leachate were injected in each pilot. They were kept in contact with the waste for 2 h and then drained by gravity; almost 70% of the injected leachate was recovered by

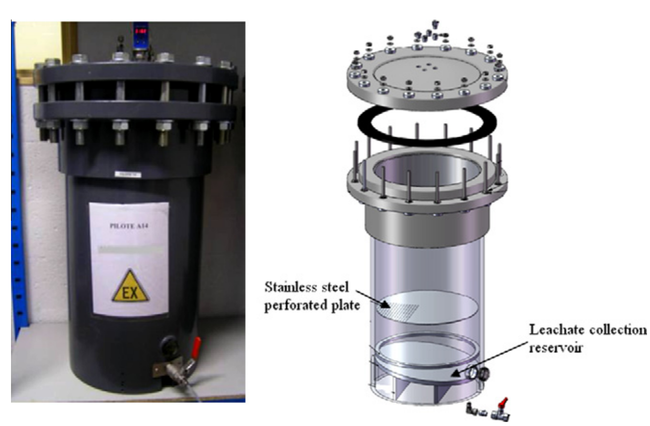

Fig. 1. Photo of a 68 L pilot used in the study (left) and schematic presentation (right).