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Stabilization of fine fraction from landfill mining in anaerobic and aerobic laboratory leach bed reactors

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ABSTRACT

Fine fraction (FF, <20 mm) from mined landfill was stabilized in four laboratory-scale leach bed reactors (LBR) over 180 days. The aim was to study feasibility of biotechnological methods to treat FF and if further stabilization of FF is possible. Four different stabilization methods were compared and their effects upon quality of FF were evaluated. Also during the stabilization experiment, leachate quality as well as gas composition and quantity were analyzed. The methods studied included three anaerobic LBRs (one without water addition, one with water addition, and one with leachate recirculation) and one aerobic LBR (with water addition). During the experiment, the most methane was produced in anaerobic LBR without water addition (18.0 L CH_4/kg VS), while water addition and leachate recirculation depressed methane production slightly, to 16.1 and 16.4 L CH_4/kg VS, respectively. Organic matter was also removed via the leachate and was measured as chemical oxygen demand (COD). Calculated removal of organic matter in gas and leachate was highest in LBR with water addition (59 g COD/kg VS), compared with LBR without water addition or with leachate recirculation (51 g COD/kg VS). Concentrations of COD, ammonium nitrogen and anions in leachate decreased during the experiment, indicating washout mechanism caused by water additions. Aeration increased sulfate and nitrate concentrations in leachate due to oxidized sulfide and ammonium. Molecular weight distributions of leachates showed that all the size categories decreased, especially low molecular weight compounds, which were reduced the most. Aerobic stabilization resulted in the lowest final VS/TS (13.1%), lowest respiration activity (0.9–1.2 mg O_2/g TS), and lowest methane production after treatment (0.0–0.8 L CH_4/kg VS), with 29% of VS being removed from FF. Anaerobic stabilization methods also reduced organic matter by 9–20% compared with the initial amount. Stabilization reduced the quantity of soluble nitrogen in FF and did not alter concentration of soluble and insoluble phosphorus, and insoluble nitrogen. All four stabilization methods decreased organic matter and thus are possible stabilization methods for FF, but aerobic treatment was the most efficient in this study.

1. Introduction

For decades, landfill has been the main method of disposal for municipal solid waste (MSW) from households, industry, commerce, trade, and administration. Landfill mining refers to the excavation, processing, treatment, and recycling of waste materials mined from landfill. It recovers resources for raw material or energy purposes, but also diminishes both local and global emissions and provides additional space, for example, for landfill or other purposes (Krook et al., 2012). Previously, it has been reported that fine fraction (FF) accounts for a large part of landfill's content; 38.0–53.9% of total landfill waste is under 20 mm in a landfill in Kuopio, Finland (Kaartinen et al., 2013), 44 ± 12% under 10 mm in a landfill in Belgium (Quaghebeur et al., 2013) and 50–52% under 25.4 mm in a landfill in New Jersey, USA (Hull et al., 2005). FF has been defined as consisting of soil-type materials, biodegraded waste and very little amounts (less than 10% (w/w) in total) of plastics, paper, cardboard, textiles and metals (Kaartinen et al., 2013; Quaghebeur et al., 2013). FF has a poor potential heating value (Quaghebeur et al., 2013), suggesting that other purposes for FF, apart from thermal treatment, need to be identified. Different uses and/or disposal techniques for FF require different characteristics, and in most cases, stabilization is needed to ensure the safety of these techniques.

Stabilization improves the quality of the waste, reducing organic and inorganic pollutants (Hrad et al., 2013). The stability of the waste is significantly influenced by moisture and the organic

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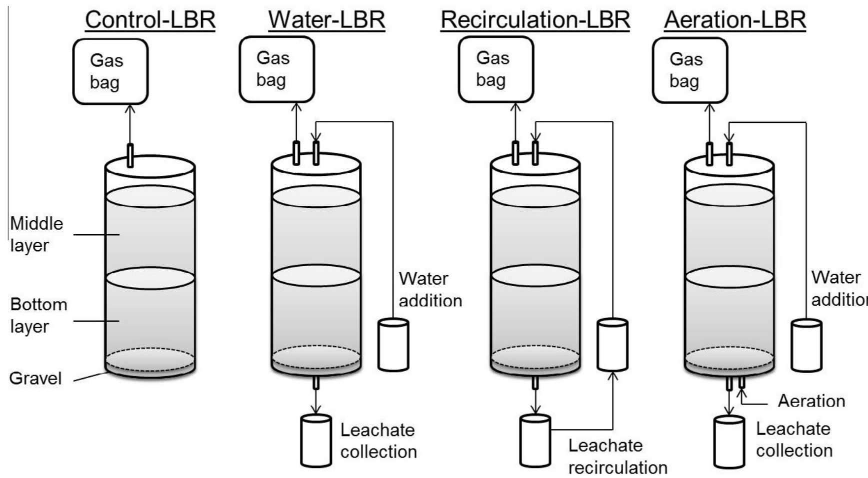

Fig. 1. Schematic configuration of leach bed reactors (LBRs) used for stabilization of fine fraction with four different methods.

matter content of the waste material (Sri Shalini et al., 2010), but the point of the stability for different purposes (utilization or disposal) is not clearly defined (Kelly et al., 2006; Valencia et al., 2009a). A combination of different parameters, such as waste composition, leachate quality, and biological activity, should be measured when defining the stability of the waste (Ritzkowski et al., 2006). In European Union (EU) countries, if waste material is disposed of in landfill after stabilization, it must fulfill the criteria for acceptable landfill waste, according to EU legislation (EC, 2003).

The stabilization of waste can be achieved using biotechnological anaerobic and aerobic processes, and those methods could also potentially be considered for FF. Bioprocesses are enhanced by the pre-treatment of wastes via methods such as particle size reduction and process conditions; for example, recirculation of leachate and adjustment of moisture content, pH, and temperature (Mali et al., 2012). The advantages of enhanced stabilization include the improved generation and quality of produced biogas, the reduction of the environmental impact (via leachate and gas emissions, for example), and settlement, which reduces the volume of the waste (Warith, 2002). Leachate recirculation is a technique that has been used widely for fresh solid waste stabilization in laboratory scale reactors, because it can enhance stabilization by increased moisture content, reduces organic content by leaching and also reduces the volume of leachate (Šan and Onay, 2001; Sponza and Ağdağ, 2004; Valencia et al., 2009b). Aeration has been studied increasingly as a method to control municipal solid waste landfill (Raga and Cossu, 2013). Aeration can be a more rapid method to stabilize waste than anaerobic stabilization; it reduces methane emissions and removes moisture from material, and it may degrade compounds that cannot be degraded in anaerobic conditions (Reinhart et al., 2002).

The aim of this study is to evaluate feasibility of biotechnological methods for reducing the organic matter content in FF mined from 1- to 10-year old landfill, with the goal of stabilization, which improves the potential for different applications of FF or opportunities for disposal. Previous studies have focused on the stabilization of fresh municipal solid waste and landfill waste mined from landfill, but not solely for FF, as is the case in this study. In the present study, an experiment was performed using four laboratory leach bed reactors (LBR), with the aim of simulating different stabilization methods. The methods studied were anaerobic stabilization in LBR (with and without semicontinuous water addition, and with leachate recirculation) and aerobic stabilization in LBR (with water addition). These methods could be considered for FF treatment in a heap of landfill near a landfill mining site, for example. The effects of the different stabilization methods on FF were compared, and the quantity and composition of biogas (CH_4) and quality of leachate (chemical oxygen demand (COD), ammonium nitrogen, anions, molecular weight distribution) were examined.

2. Materials and methods

2.1. Sampling and processing fine fraction

Landfill material was obtained from a landfill site in Kuopio, Central Finland, landfilled between 2001 and 2011. Landfill has a sealed bottom structure according to the EU requirements, and vertical gas collection wells were installed during the sampling in July 2012. Between 2001 and 2004, the landfill was filled with MSW. Between 2004 and 2009, biowaste was source segregated from landfilled MSW. After 2009, MSW was mechanically pretreated and sieve underflow (<70 mm) was landfilled. Samples were taken from three vertical wells at two different depths, referred to as the “middle layer” (sampling depths of 2 to 10–15 m) and the “bottom layer” (sampling depths of 10–15 to 22–31 m). It is estimated that the bottom layer represents years 2001–2005 and the middle layer years 2006–2011. Samples were manually sieved and FF (<20 mm) was found, on average, to make up 43% (w/w) of the middle layer samples and 47% (w/w) of the bottom layer samples. Kaartinen et al. (2013) showed that the FF from the Kuopio landfill site contained less than 10% (w/w) of energy fractions like plastics, textiles, paper and cardboard.

The total solids (TS) and volatile solids (VS) in the six FF samples were analyzed. In the middle layer samples, the TS was 55–67% (with the balance being water) and the VS was 12–17%. In the bottom layer samples, the moisture content was higher (TS 46–56%) and the organic matter content was lower (VS 8–11%) than in the middle layer samples. In the LBR experiments, three middle layer samples were mixed together to make a new middle layer sample (TS 60% and VS 13%) and three bottom layer samples were also mixed to make a new bottom layer sample (TS 52% and VS 10%).

2.2. Leach bed reactors

Four parallel LBRs made of acryl (height 600 mm, diameter 150 mm) were filled with 5.8 kg of FF (Fig. 1). The bottom half (22 cm) of the reactor was filled with the mixed bottom layer