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Aeration of the teuftal landfill: Field scale concept and lab scale simulation

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ABSTRACT

Long lasting post-closure care (PCC) is often the major financial burden for operators of municipal solid waste (MSW) landfills. Beside costs for the installation and maintenance of technical equipment and barriers, in particular long term treatment of leachate and landfill gas has to be paid from capital surplus. Estimations based on laboratory experiments project time periods of many decades until leachate quality allows for direct discharge (i.e. no need for further purification). Projections based on leachate samples derived from the last 37 years for 35 German landfills confirm these assumption. Moreover, the data illustrate that in particular ammonium nitrogen concentrations are likely to fall below limit values only after a period of 300 years.

In order to avoid long lasting PCC the operator of Teuftal landfill, located in the Swiss canton Bern, decided to biologically stabilize the landfill by means of a combined in situ aeration and moisturization approach. In December 2014 the aeration started at a landfill section containing approximately 30% of the total landfill volume. From summer 2016 onwards the remaining part of the landfill will be aerated. Landfill aeration through horizontal gas and leachate drains is carried out for the first time in field scale in Europe. The technical concept is described in the paper.

Parallel to field scale aeration, investigations for the carbon and nitrogen turnover are carried out by means of both simulated aerated landfills and simulated anaerobic landfills. The results presented in this paper demonstrate that aeration is capable to enhance, both carbon mobilization and discharge via the gas phase. This effect comes along with a significant increase in bio-stabilization of the waste organic fraction, which positively affects the landfill emission behavior in the long run. In terms of leachate pollution reduction it could be demonstrated that the organic load decrease fast and widely independent of the adjusted aeration rates whereby ammonium nitrogen load efficiently decrease later and only under higher aeration rates.

1. Introduction

The Teuftal landfill, located in the Swiss canton Bern, is the largest sanitary landfill in Switzerland. For more than 40 years both, municipal solid waste (MSW), construction and demolition waste, bottom ashes, flue gas cleaning residues as well as industrial waste are disposed of at different landfill sections. Untreated MSW has been landfilled between 1973 and 2000 on an area of approximately 12 ha. This section of the landfill which contains approx. 3.2 million tons of waste (approx. 2.1 million tons dry matter) is hereafter referred to as bioreactor. Based on the available records regarding the landfilled waste materials it can be assumed that the amount of organic carbon in the fresh MSW was in a range of 18–20% based on dry mass. Since 1 January 2000, landfilling of organic waste is prohibited in Switzerland (Schweizerischer Bundesrat, 1990). Consequently, the bioreactor has been covered with biologically non-reactive waste (slightly contaminated soil) during the past 16 years.

Between 1982, when landfill gas (LFG) collection started for the first time, and 2013 a total of approx. 256 million m^3 LFG at an average methane concentration of 45% (average CO_2 concentration: 32%) has been collected from the bioreactor and used for combined electrical and thermal energy production. Since 1996 the collected amounts of LFG declined significantly down to hourly mean values well below 100 m^3/h in 2013. At the same time, analysis results for leachate samples taken directly out of the most

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reactive zone of the bioreactor still exhibited significant concentrations particularly for ammonium-nitrogen (NH_4-N, up to 1500 mg/l) and dissolved organic carbon (DOC, up to 600 mg/l).

In order to diminish long lasting PCC associated with severe costs and monitoring efforts (Heyer et al., 2005; Laner et al., 2012), the landfill operator in cooperation with the Hamburg University of Technology decided to biologically stabilize the bioreactor by means of a combined in situ aeration and moisturization approach. According to Heyer et al. (2005) the net costs for investment and operation of aerated landfills range from € 1.1 to € 3.0 per m^3 of aerated waste material. However, the investment made during and for the aeration will pay out through reduced expenditures for long term leachate and LFG treatment as well as monitoring. It is expected, that total cost reductions of at least 10–25% are possible as regards closure and aftercare measures. In December 2014 the aeration started at a section of the bioreactor containing approx. 30% of its total waste volume. There, landfill aeration using horizontal gas and leachate drains for air injection and off-gas extraction is carried out for the first time in full scale. The applied technology differs significantly from other approaches previously reported for landfills in Switzerland (Bachofner et al., 2010). Section 2 provides an overview on the technical concept applied for biological stabilization of the bioreactor. The stabilization processes is currently ongoing. First intermediate results from this field scale study are provided whilst final results will be presented at a later date. Sections 3 and 4 present the set-up and major findings from lab scale simulation tests which have been conducted in parallel to the field scale study.

2. Stabilization concept (field scale)

2.1. In situ aeration

Under consideration of site specific conditions it was decided to implement a large scale in situ aeration trial on Section 3 of the bioreactor. This section covers an area of approx. 4.8 ha and contains approx. 557,000 m^3 of MSW. Based on an estimated wet waste density of 1.2 ton per m^3 and a measured average moisture content of 35.5% (wt), the total amount of dry waste in bioreactor Section 3 is calculated to approx. 431,100 tons.

The aeration is realized using the existing horizontal gas and leachate drainage networks. Between 1987 and the year 2000, a total of 6 drainage networks have been installed at a vertical spacing of approx. 7 m. The highest situated drainage network (N6) is located directly at the interface between bio-reactive and non-reactive wastes and functions as a protection against water infiltration into the bioreactor. In contrary, network N1 is located closest to the valley bottom. The waste layer at the landfill base is considered low in bio-degradability, due to its age and composition (in particular higher amounts of excavated soil). Through the N1 network leachate originating from the bioreactor can be effectively drained out of the landfill. Each drainage network consists of a main drainage pipe and a number of smaller inlet lines. The latter branches off at an angle of 45° and a horizontal distance of 18–20 m. The minimum slope towards the main collection pipes is 5%. Fig. 1 shows a cross section of the bioreactor (Section 3) and provides an overview on the location of the drainage networks.

The aeration of bioreactor Section 3 was initiated in December 2014. During the initial stabilization period ambient air is injected into a total of 3 horizontal drainage networks (N1, N3 and N5) whereas the other 3 networks are used for parallel off-gas extraction. In order to diminish any diffuse gaseous emissions, the upmost drainage network is subject to off-gas extraction only whilst for moderate aeration of the underlying older waste mass the lowest network is permanently aerated. The remaining 4 intermediate drainage networks will be altered in their specific operation mode (either air injection or off-gas extraction) in order to ensure a widely aerobization of the deposited wastes and to avoid the potential formation of preferential flow paths.

At present, the devices for aeration and off-gas extraction are operated at an intermittent mode. Following a 100-min operation phase the blowers are turned off for a down time of approx. 20 min. During down time the drainage networks are depressurized which allows for the drain-off of leachate. The injected amount of oxygen is widely consumed during down times and the pressure variations during start up and close down positively contribute towards the intended complete distribution of air in the landfill section. Moreover, the operation mode ensures moderate energy consumption by the total bio-stabilization system which is further aided by the special type of blowers chosen for aeration and off-gas extraction. The installed screw type compressors are capable to operate at pressures up to 300 mbar whilst consuming approx. 30% less energy in comparison to rotary piston compressors which are often used for landfill aeration.

In comparison with other projects for low pressure aeration the required positive pressure differences for air injection at the Teuftal landfill are significantly higher. The usually reported pressure differences are in a range of 20–80 mbar and may, according to definition, not exceed 0.3 bars in maximum (Ritzkowski and Stegmann, 2012). For air injection into Section 3 of the bioreactor up to 250 mbar is required in order to realize an air volume of approx. 990 m^3/h. These higher pressures are due to the significant load caused by the MSW and the overlaying non-reactive waste layer, in combination with the specific installations used for air injection (i.e. horizontal drainage networks). In the extreme case at the lowest drainage system N1, a load of up to 54 Mg/m^2 can be expected.

The off-gas extracted from Section 3 is directly transferred into the upper drainage networks of the adjacent Sections 1 and 2 of the bioreactor. This strategy has been chosen in order to enable a pre-aeration of the remaining landfill sections associated with a reduction in the required aeration period. Along with the slight aeration caused by the residual oxygen content in the off-gas, a further aspect of the off-gas transfer comes with the biological oxidation of residual methane. The latter is expected to take place mainly during the perfusion of the gas through the overlaying non-reactive waste material.

Based on the results of the online monitoring system a specific carbon mobilization rate of 1.76 Mg/d (SD = 0.37) has been realized during the first 13 months of in situ aeration. The carbon load is calculated for the average volume of extracted off-gas (i.e. 1009 m^3/h from December 2014 until December 2015) and continuously analyzed concentrations of carbon dioxide (mean value: 9% v/v) and methane (mean value: 4.4% v/v). The specific carbon load in the off-gas was in the range of 65–84 g per m^3 (mean: 72 g/m^3; SD: 0.01).

2.2. In situ moisturization

Although the average moisture content of the waste in Section 3 (35.5% by mass, based on wet waste, see Table 1) can be considered sufficient for aerobic bio-decomposition, some zones exhibit significantly lower moisture contents of down to 18.4%. At these low moisture levels bio-degradation processes are limited and may even be inhibit completely (Liang et al., 2003). Moreover, through the extraction of water saturated off-gases from the landfill in combination with increased transpiration rates under elevated waste temperatures, the aeration process may contribute towards decreasing moisture content of the landfilled waste in the bioreactor (Ritzkowski, 2013).