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INTENSIFIED MONITORING AS A BASIS FOR DOCUMENTATION AND EVALUATION OF LANDFILL AFTERCARE

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SUMMARY: Landfill aftercare lasts until the authorities consider a landfill not to pose a threat to human health and the environment. To evaluate aftercare, it is necessary to gain an understanding of the waste emission behaviour, the long-term barrier performance, and the impact of substances released to the environment. Because appropriate models for emissions from waste are highly dependent on full-scale monitoring data, it is the aim of this study to illustrate monitoring procedures suitable for generating data to establish such models. Based on a case study about an Austrian landfill, it could be shown that process-oriented monitoring data form the basis for calibrating and validating (long-term) leachate emission models, on the one hand, and for providing reliable documentation of leachate emission developments, on the other hand. Therefore, intensified leachate monitoring schemes were implemented also at three other closed MSW landfills in Austria, where process-oriented monitoring is expected to provide a basis for robust evaluation and optimization of aftercare.

1. INTRODUCTION

Municipal solid waste (MSW) landfills represent a source of potential pollution for long time and therefore need to be managed after closure (Belevi and Baccini 1989). This period of aftercare lasts until the authorities consider a landfill not to pose a threat to human health and the environment (cf. European Parliament 1999). In order to evaluate aftercare, it is hence necessary to gain an understanding of the waste emission behaviour, the long-term barrier performance, and the impact of substances released to the environment (Laner et al. 2012). Because the transferability of lab-scale results derived from waste degradation experiments is limited (e.g. Kylefors et al. 2003, Fellner et al. 2009) and modelling the complex waste degradation processes in a landfill system remains an enormous challenge (e.g. Van Turnhout et al. 2013), reliable full-scale monitoring data are of particular importance for assessing the performance of aftercare measures and potential aftercare completion. Therefore, it is the aim of this work to illustrate the potential of process-oriented monitoring of landfill leachate as a basis for building and calibrating leachate emission models.

The use of process-oriented leachate monitoring for understanding the relationship between leachate generation and leachate contamination and as a basis for improving emission modelling is illustrated via a case study on the Breitenau landfill in Austria. Based on such monitoring schemes

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it can be shown that higher leachate discharge rates go along with lower pollutant concentrations in the leachate, which can be explained by dilution of leachate with infiltrating rainwater due to preferential water flow (cf. Laner et al. 2011b). The current quality of monitoring data is critically analysed and suitable protocols for capturing leachate discharge dynamics and the corresponding leachate quality are presented. In addition, similar monitoring schemes implemented at three other closed MSW landfills are described. Finally, the implications of better quality leachate monitoring data for landfill aftercare evaluation are discussed and an outlook on the further monitoring at the case study landfills is provided.

2. MATERIAL AND METHODS

2.1 Case study landfills

The Breitenau landfill is an experimental MSW landfill located in the East of Austria, around 60 km south of Vienna. At the site approximately 95,000 tonnes of MSW were disposed of during 1987 and 1988. The site is divided into three landfill compartments, which were equipped with different top covers (soil covers or gravel-soil layers with or without compost on top) and with different base liner systems. After 21 years of temporary cover, a final cover (composite liner system) has been constructed in 2009. The local climate is relatively dry with an average annual precipitation of 633 mm per year. In the present study, we draw on monitoring data collected during the period after the end of waste deposition until the installation of the final cover (from 1989 until 2009), because the landfill was closed and the soil cover still allowed for rainwater to percolate through the landfill (i.e. precipitation had a direct effect on leachate generation rates). The Breitenau landfill is a particulary well monitored landfill, because it served as an experimental site for numerous research studies (e.g. Binner et al. 1997, Fellner et al. 2009, Laner et al. 2011b).

In addition to the Breitenau landfill, extended leachate monitoring schemes were introduced at three other closed Austrian MSW landfills. Landfill A is a rather small MSW landfill in the West of Austria (closed in 2004 with a total waste deposition volume of 135,000 m³) with humid, continental climate (precipitation: 1960 mm/yr; potential evaporation: 550 mm/yr). Landfill B is also located in the West of Austria at a site, where around 1.3 million tonnes of waste was disposed of in a former gravel pit. The landfill was closed in 2007 and in 2008 a temporary cover was installed (soil cover). The annual precipitation is approximately 1200 mm per year with potential evapotransporation being 550 mm/yr. Finally, Landfill C is also a closed MSW landfill located in the East of Austria at a site with an average precipitation of 740 mm/yr, where 540,000 tonnes of waste were disposed of between 1984 and 2002. A top cover was installed in 2002 (clay liner with soil layer above) reducing leachate generation to around 10% of annual precipitation. All the case study landfills are equipped with base liner systems, ranging from clay liners to composite liner systems (plastic liner above clay liner). The collected leachate is either treated in a waste water treatment plant at the site (Landfill B) or transported to a waste water treatment plant off site (Breitenau landfill, Landfill A and C).

2.2 Intensified leachate monitoring

The purpose of high resolution leachate monitoring is to better understand the relationship between leachate generation rates and pollutant concentrations in the leachate. Based on this understanding, it is possible to a) perform monitoring for key leachate parameters and derive other parameter values using established correlations, b) adapt observations made during different leachate regimes (routine monitoring) to the average leachate generation rate used in the emission model, and c) calibrate model predictions for different hydraulic conditions, e.g. after a final cover has been installed at the site.

2.2.1 Monitoring data vs. model predictions

The model used for estimating the mean concentration of a specific substance in the leachate as a function of the liquid-to-solid ratio is based on a first-order decay model developed by Belevi and Baccini (1989), but modified as follows: heterogeneity of water flow in the waste is considered via a correction factor and different substance release rates due to the continuous degradation of organic matter are taken into account (cf. Laner et al. 2011a). The use of monitoring data after landfill closure for estimating the model parameters (i.e. model calibration) and the need for confirming model predictions via future monitoring (i.e. model validation) are schematically illustrated in Figure 1. The model is based on the assumptions of decreasing leachate emission trends and of stable conditions at the landfill and in the waste (i.e.no drastic change of water flow patterns, no change of dominant substance release mechanisms).

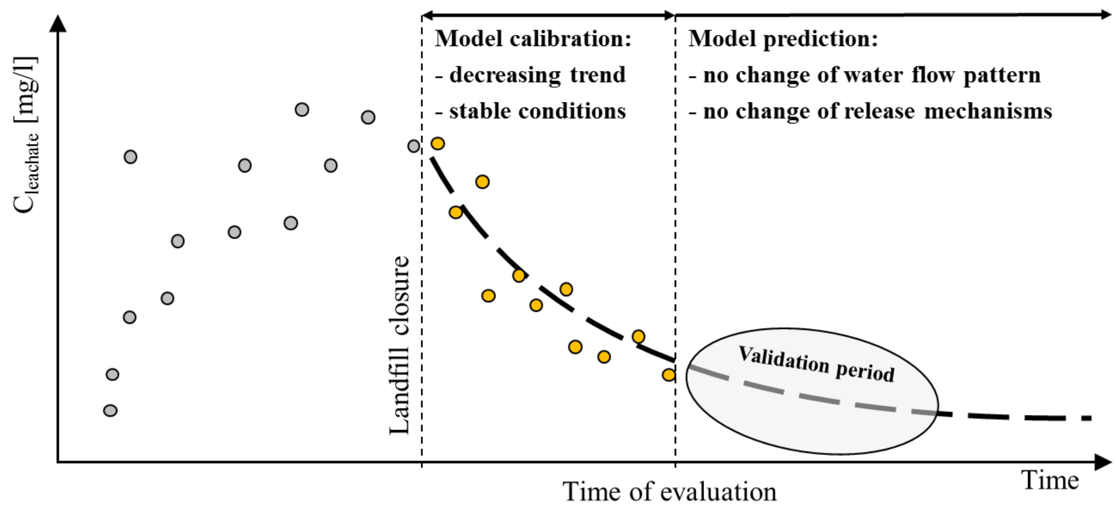

Figure 1. Schematic illustration of calibration and validation of leachate emission model based on aftercare monitoring data.

2.2.2 Process-oriented leachate monitoring schemes

The intensified monitoring at the case study landfills consists of continuous measurements of electric conductivity (EC) and temperature using sensors installed in the leachate collection pipe or at the inflow to the leachate tank. Leachate generation rates are either continuously measured via inductive flow meters (Breitenau landfill) or derived from leachate pumping volumes and water level changes in storage tanks documented with high temporal resolution (Landfill A, B, and C). Furthermore, several major leachate parameters (i.e. parameters which do not comply with current limit values for discharge into the sewer system) are determined 4-6 times per year during different leachate discharge regimes (high, middle, and low discharge). Based on these analyses and the continuous measurements of EC and leachate generation rates, correlations are established between these factors. Ultimately, these correlations should allow for decreasing the frequency of leachate sampling on the longer run (after 2-3 years), because a lot of information about leachate quality can be extrapolated from electric conductivity measurements and leachate generation rates.

3. RESULTS AND DISCUSSION

Results from the leachate monitoring and data analysis are shown for the Breitenau landfill in this section, because quality-assured data from the monitoring at the landfills A, B, and C are not yet available for longer time periods. The intensified monitoring has been implemented in spring 2014 at these sites and the implementation phase (installation and calibration of devices, operational adaptations, cross-checking with independent measurements) has been (more or less) completed by the end of 2014. Therefore, measurement data for investigating parameter relationships and correlations are not yet available to a larger extent at these sites.

3.1 Relationships between leachate quantity and quality

The relationship between leachate generation rates and electric conductivity (EC) is shown in Figure 2 for compartment 1 (35,000 m³ of waste volume) of the Breitenau landfill between 2003 and 2009. Whereas no significant decrease in the average EC of the leachate was observable during this period of monitoring, variations in EC can be directly related to variations in the leachate generation rate. A log-linear relationship is established: the higher the leachate generation rate, the lower the EC of the leachate. Thus, abrupt changes in the leachate's EC are primarily caused by the dilution of leachate with (fast infiltrating) rainwater during events of high leachate discharge.

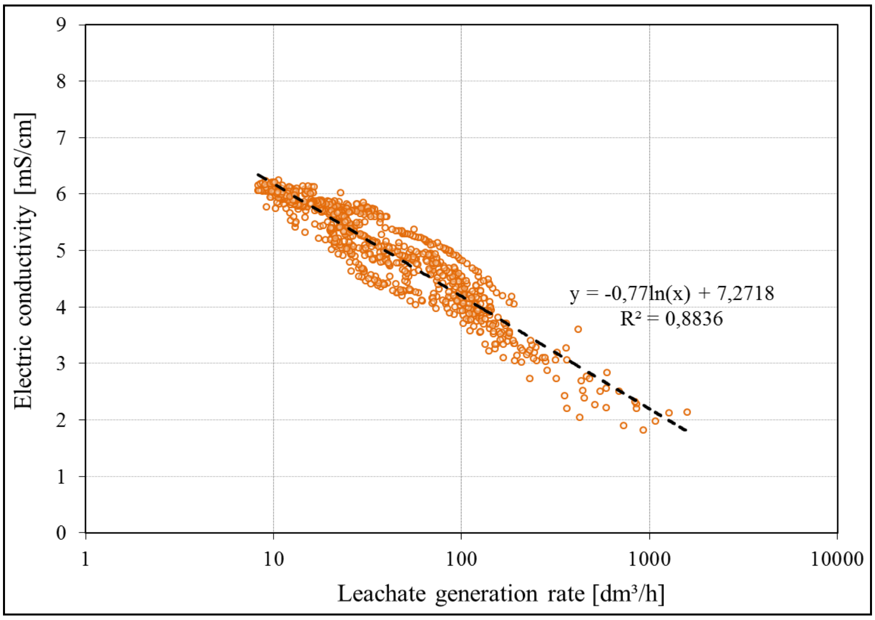

Figure 2. Correlation between Breitenau landfill's leachate discharge and its electric conductivity.

Based on the combination of leachate sampling and analysis with continuous EC monitoring data, linear regressions between various leachate parameters and EC measurements are formulated. The measurement data and the regression models for ammonium nitrogen concentrations and EC as well as for chloride concentrations and EC are shown for the leachate of compartment 1 of the Breitenau landfill in Figure 3. Thus, strong relationships between leachate generation rates and various leachate parameters (e.g., soluble salts, ammonia nitrogen) can be observed and used to predict NH_4-N or Cl concentrations in the leachate based on continuous EC monitoring.

Although the general trend in leachate concentrations is well reflected by the emission model for compartment 1 of the Breitenau landfill (Figure 4a), the deviations of individual monitoring data from the model curve are substantial (up to factor 3). Because this variation in measured values is primarily caused by leachate dynamics (Laner et al. 2011b), i.e. sampling during a period of high discharge vs. low discharge, it cannot be reproduced by the model (model outputs represent leachate concentrations related to the annual average leachate discharge rate). Therefore, the correlations described between leachate discharge, EC, and selected parameters are used to transform measured data of leachate composition at various leachate generation rates (and thus dilution rates) into leachate concentrations characteristic for the average annual leachate discharge assumed in the emission model. This transformation results in a drastic reduction of "noise" in the data (see Figure 4b) and leads to a 60% reduction of the squared errors between adapted measurements and model estimates compared to the case using untransformed measurements (Figure 4: a vs. b).

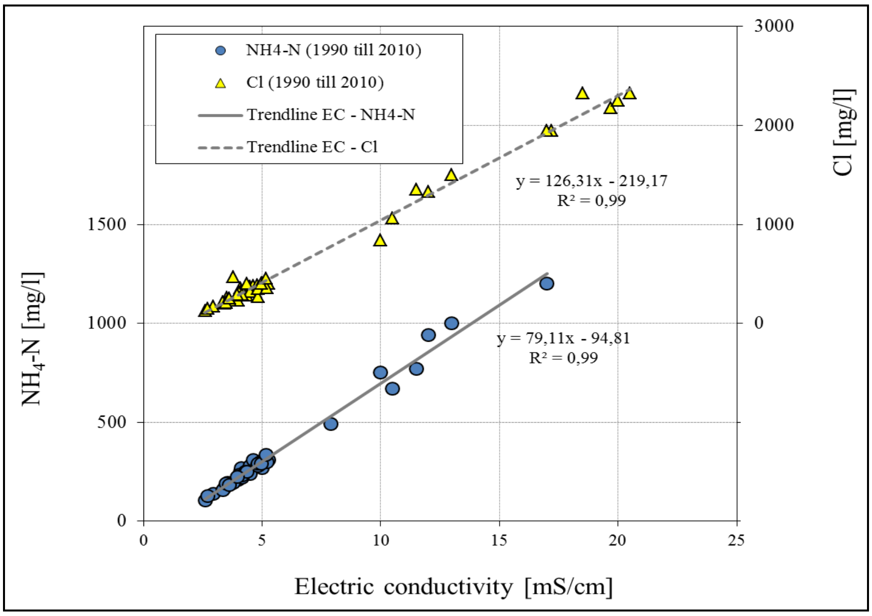

Figure 3. Correlation between ammonium nitrogen and chloride concentrations in the leachate of the Breitenau landfill.

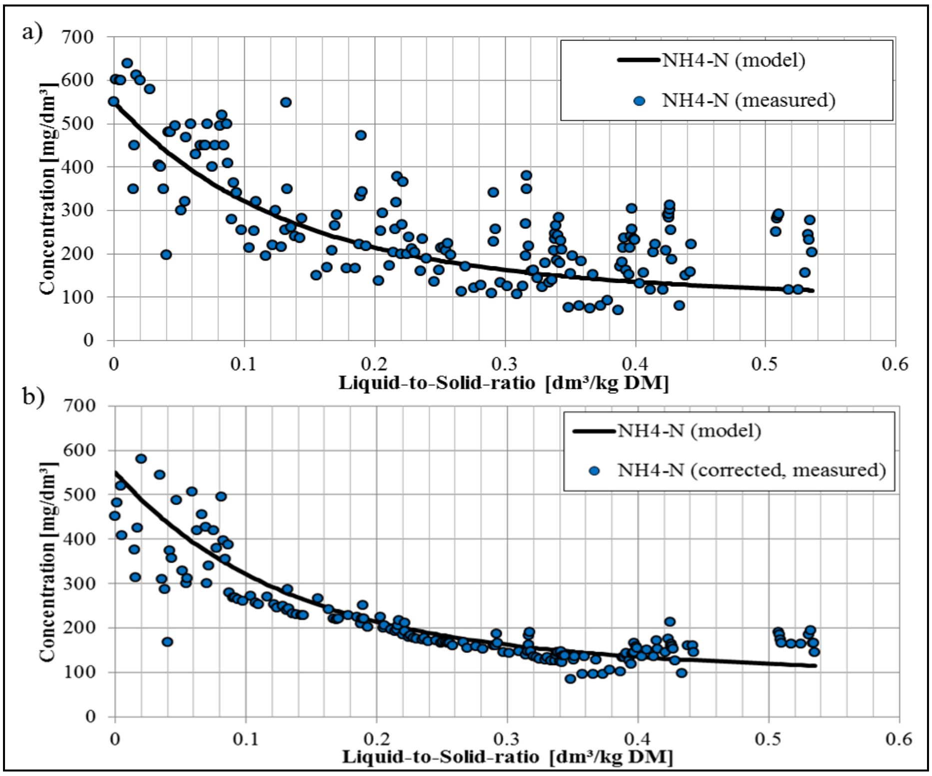

Figure 4. Ammonium nitrogen model estimates vs. monitoring data: a) using original measurements at different discharge regimes (top); b) transformation of measurements to correspond to the average annual leachate discharge rate (bottom).

4. CONCLUSIONS AND OUTLOOK

Based on high resolution leachate monitoring data of the Breitenau landfill, it was possible to establish robust relationships between leachate generation rates and leachate pollutant concentrations. The corresponding regression models could be used to “correct” measurement data for the effect of leachate dynamics on pollutant concentrations and thereby allowed for better correspondence between monitored (and corrected) leachate characteristics and emission model predicitions. Therefore, process-oriented monitoring data form the basis for calibrating and validating leachate emission models, on the one hand, and for providing reliable documentation of leachate emission developments as a basis for aftercare performance evaluation, on the other hand. Both, confidence into emission models to predict future leachate contamination as well as reliable documentation, are crucial elements of protocols for aftercare evaluation and completion.

Monitoring schemes similar to the Breitenau landfill have been implemented at three other closed MSW landfills in Austria. These sites have been subject to aftercare evaluation and the increased process understanding with respect to leachate dynamics and characteristics will enable more robust evaluations of the effect of aftercare measures on leachate emissions.

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