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In-Situ Treatment Methods Capable to Achieve Final Storage Quality?

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Abstract
The "Precautionary Principle" outlined in the Austrian Waste Management Act demands that landfilled waste will not be a burden for following generations, which means that the necessary aftercare period of landfills should not exceed 30 years. Since existing municipal solid waste landfills do not meet this criterion, different in-situ treatment methods have been proposed to accelerate the decomposition of the waste which results in a shortening of the aftercare period.

The present paper discusses the two in-situ methods flushing and aeration that have been heavily pushed in the recent years. By means of different results from field and laboratory experiments, it is shown that both methods have limited impact on the overall landfill stabilization due to the heterogeneous character of disposal sites.

1 Introduction
The greatest part of the solid waste generated world wide is deposited in landfills without any pre-treatment. The environmental impacts of those landfills are associated mainly with the emissions of leachate and biogas. While biogas emissions will become negligible within decades, leachate emissions will stay on an environmentally incompatible level for hundreds of years. Belevi & Baccini (1987), Stegmann (1995) and Ehrig & Krümpelbeck (2001) assessed necessary durations for the aftercare period of 200 to 500 years.

In the last two decades water and water flow were identified as the main factors determining the metabolism of MSW landfills, as water is on the one hand essential for the biochemical decomposition of the organic substance and on the other hand needed for leaching of soluble compounds. Different investigations (Klink & Ham, 1982; Bogner & Spokas, 1993) showed that enhanced water flow through waste leads to an acceleration of biochemical processes, as water is the only carrier of substances within a landfill and only water flow facilitates the redistribution of chemicals, micro-organisms and nutrients. Based on these observations different concepts have been developed to shorten the aftercare period. They include unhindered precipitation input (permeable cover layers), leachate

recirculation, and forced flushing of pollutants ("Flushing-Bioreactor"). It is assumed that the duration of the aftercare period is more or less inversely proportional to the water flow rate through the landfill.

Beaven & Walker (1997) determined a required water amount of 6 to 7 m^3/ t(DS) municipal solid waste (MSW) to stabilize the waste. Similar results were obtained by Allgaier et al. (2003), who observed that old small depositions of MSW have negligible hazardous potential if the liquid-solid ratio is higher than 5. This equals to an amount of water of 7.2 m^3/t (DS) MSW assuming that the initial water content of MSW is 30 %. All these data are derived either from small scale experiments in the laboratory using so-called landfill simulation reactors (LSR) with an experimental volume between 0.1 and 1 m^3 of waste or from small landfills with an average height of less than 4 m.

The application of LSR results to full scale landfills, indirectly, implies a similar moisture distribution within full scale landfills and LSR. However, recent investigations summarized in this paper indicate that due to the big difference in the scale the waste body of LSR is much more homogenous compared to existing landfills with volumes up to some million m^3.

2 Methodology

The study presented is based on investigations of a full scale landfill (see Figure

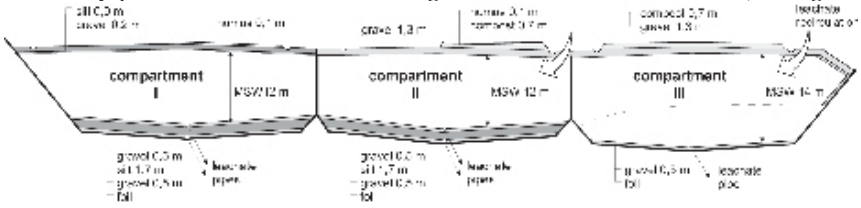


Fig. 1: Cross-section of the full scale landfill Breitenau (Huber et al., 2004)

1, waste volume ~ 100,000 m^3) and typical landfill simulation reactors with a volume of less than 0.15 m^3 (see Figure 2). Both systems consider the same waste, as representative waste samples were taken from the landfill and built in the laboratory reactors.

Tracer experiments using a dye (uranine) were performed to characterize the hydraulics of the waste in the landfill and the simulation reactors. The experiments resulted in a break-through-curve (tracer concentration vs. time). This curve was analyzed applying the transfer-function-model as described in Jury (1986) in order to calculate the median of the tracer travel time and the solute transport volume fraction. By plotting the bed volume of leachate having passed the waste

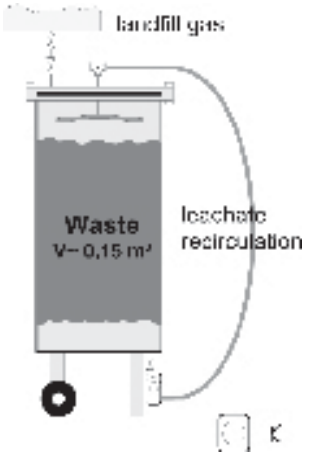


Fig. 2: Landfill Simulation Reactor (Döberl et al., 2005)

against the tracer mass flow it was possible to characterize the influence of preferential paths on the water flow. A detailed description of the tracer experiments is given in Döberl et al. (2002, 2005).

Additionally to the tracer tests, element balances for easy soluble compounds (e.g. chloride) were conducted. The results of these balances demonstrate the influence of the hydraulic behavior on the metabolism of disposed waste.
In addition to the investigations of the leachate path, various literature data concerning the distribution of methane emissions on the surface of landfills were analyzed to characterize the gas flow and gas distribution inside landfills.

3 Results

3.1 Tracer experiments

Three days after injecting the tracer on the waste surface of the landfill uranine was detected in the leachate at the bottom (landfill height

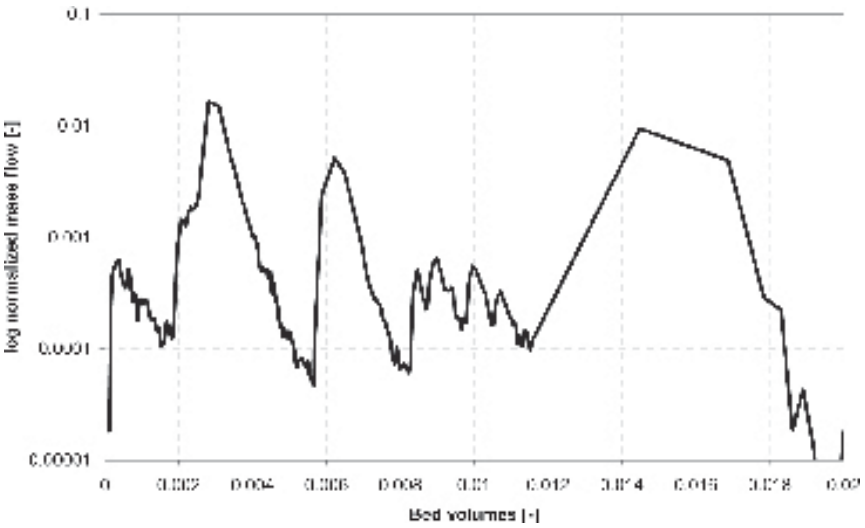
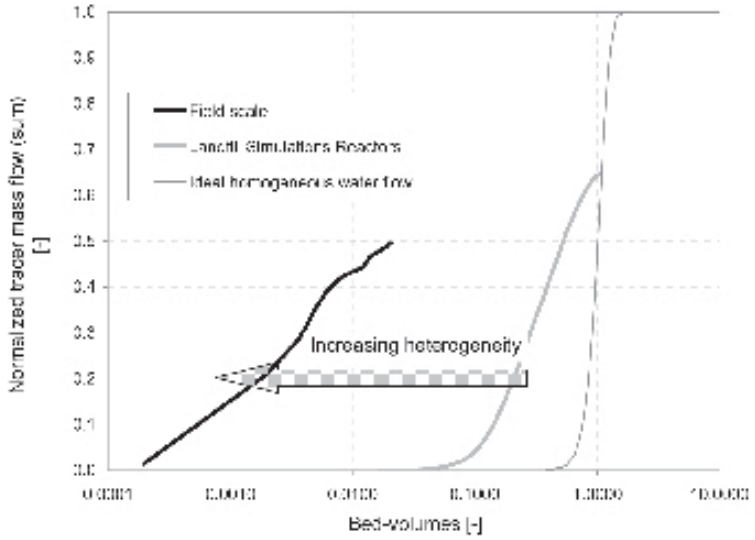


Fig. 3: Tracer mass flow (normalized) vs. bed volumes (Döberl et al., 2002)

> 10 m). After ten days a first peak was observed. The main peak appeared after two months (i.e. about 0.003 bed volumes). In case of complete homogeneity and no dispersion effect, the tracer should have appeared after one bed volume. According to the leachate discharge at the investigated site one bed volume corresponds to about 15 years of landfilling. Hence, there is strong evidence for pref-



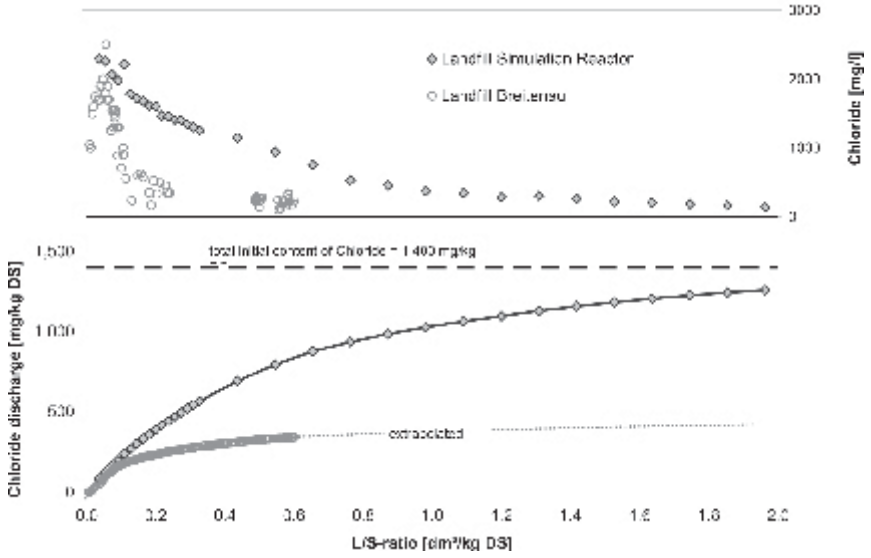
erential water flow in the landfill.
In comparison the tracer experiments carried out in the laboratory indicated a more homogeneous water distribution (see Figure 4). First detection of the tracer was noticed after a water exchange of 0.07 bed volumes, and the peak concentration of the tracer corresponded to a value of 0.2 bed volumes.

Fig. 4: Tracer mass flow (normalized) vs. bed volumes for the experiments at the Breitenau landfill and the landfill simulations reactors

For a better visualization of the hydraulic conditions in both systems (landfill and LSR), tracer flow for theoretically ideal homogeneous water distribution is illustrated in Figure 4. It is obvious that conditions in LSR were close to uniform water flow, but far away from the conditions in landfills. Consequently, the transfer of LSR results to full scale landfills has to be questioned.

The consequences of diverse water distribution on the metabolism of waste deposits were demonstrated by substance balances for highly soluble compounds. In particular, the investigations were focused on Chloride, whose emission characteristic depends only on the presence of water.

In Figure 5 the results of the substance balances are given. In the upper part of the figure the chloride concentrations of the leachates are given; and in the lower part the discharged quantity of chloride is summarized. In order to make results of different scales comparable, all data were referred to the liquid to solid ratio, a measure that gives the amount of water that passed through the waste. The initial content of soluble chloride in the investigated waste was 1,400 mg/ kg dry substance (DS). During the laboratory experiments more than 90 % of the initial load



was discharged. The water exchange rate at the end of these experiments was 2 dm^3/ kg DS, which was achieved after 8 months operation time. At field scale the water exchange rate reached a maximum value of 0.60 dm^3/ kg DS (after 16 years), which resulted in a corresponding chloride discharge of 340 mg/ kg DS.

Fig. 5: Tracer mass flow (normalized) vs. bed volumes for the experiments at the Breitenau landfill and the landfill simulations reactors

A comparison of the results shows that the same liquid to solid ratio leads to different discharge rates of chloride in the field and laboratory (lower part of Figure 5). The differences are mainly caused by diverse water routing in both systems.

These findings imply that for full scale landfills only part of the waste deposit can be stabilized by the flushing of pollutants. The remaining bulk of waste mass in landfills, that is shorted by preferential pathways, can not be accessed by this

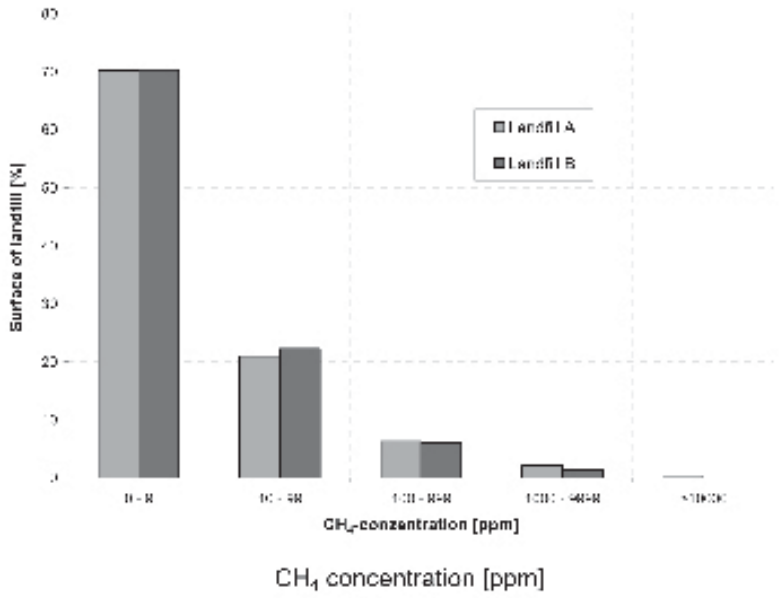


Fig. 6: Spatial distribution of methane emissions at two Austrian landfill sites (Fellner et al., 2003)

measure. However, small scale experiments in the laboratory would indicate a different result.

Similar effects as seen for the water flow can be assumed for the gaseous flow path. A good indicator for the non-uniformity of the gas flow is the distribution of methane emissions at the landfill surface. Various studies (e.g. Czepiel et al., 1996, Bogner et al., 1997) report a highly non-uniform spatial distribution.
Representative for many measurements at landfill sites, the spatial distribution of methane emissions at two Austrian landfill sites is presented in Figure 6.

Analogously to the leachate flow, the results of methane emission measurements indicate a highly non-uniform spatial distribution of gas flow. 70% of the landfill surface did not show any significant emissions, whereas more than 90% of the total methane emission load occurs over a surface area of less than 10 %.

Based on these results it can be concluded that the gas flow inside the waste deposit is highly non-uniform. This finding implicates that forced entry air will not necessarily lead to aerobic conditions throughout the whole landfill, which is of major importance for the success of aerobic stabilizations measures.

4 Summary and Conclusions

As water and air play an important role in the metabolism of landfills, increased water and/or air input into the landfill are believed to accelerate waste decomposition and thus shorten the necessary aftercare period of landfills.

The results of laboratory experiments point falsely towards sufficient acceleration of stabilization processes in wastes by forced water and/or air entry. However, flow of air and water in small scale reactors is quite uniform compared to the prevailing conditions in landfills, where a large bulk of waste cannot be accessed by the air and water added. Nevertheless actual emission levels of landfills can be decreased by such measures, though the emissions represent the decomposition stage of the waste surrounding preferential flow paths only and are therefore not representative of the whole waste deposit.

A huge emission potential of waste deposits remains unaltered when applying flushing or aeration concepts at field scale.

Acknowledgements

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