MICROBIAL REDUCTION OF METHANE EMISSIONS IN A BIOFILTER SYSTEM ON A PASSIVELY VENTED LANDFILL

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Old landfills may emit considerable amounts of methane, carbon dioxide, trace gases and odours. However, gas flow rate and/or methane content are usually too low for energetic utilization or flaring of the landfill gas. Microbial degradation is considered an alternative treatment for the reduction of methane emissions from those sites. In this connection, a biofilter unit was developed at the Institute of Soil Science, University of Hamburg, and promisingly pre-tested, showing specific methane removal rates of up to 49 g CH_4 m^{-3} h^{-1} (calculated for 30 °C).

To gather a more solid data base on the parameters of biofilter performance, a cooperative research projekt titled „Microbial Reduction of Methane Emissions“, funded by the German Federal Ministry for Education and Research (BMBF), was launched in 1999 by the Institute of Soil Science (University of Hamburg), the Department of Waste Management (Technical University of Hamburg-Harburg) and Wessel Umwelttechnik Ltd. Within the frame of this project an upflow open bed biofilter plant for the purpose of methane oxidation was installed on a Hamburg harbour sludge landfill site fitted with a passive venting system in September 2000. Despite a high total organic carbon content of up to 9 % w/w, the labile organic fraction of harbour sludge is very small. For this reason harbour sludge landfills are expected to behave similar to retired landfills with respect to gas production.

Investigations include
1. fully automated monitoring of landfill gas emission behaviour (parameters gas flow rate, gas composition, pressure, temperature)
2. biofilter performance (gas emission, distribution of CH_4 and O_2 within the biofilter material)
3. filter material characteristics (gas permeability, water holding capacity, weathering resistance) and quality of drainage water
4. microbiological investigations (cell numbers, methane oxidation activities)
5. laboratory studies on methanotrophic activity with respect to methane concentration, temperature, water tension, salt concentration and pH-value.

The fully automated high-resolution data collection system gives detailed evidence on interrelationships between atmospheric temperature and pressure and the amount and composition of landfill gas emitted as well as the pressure by which it is released via the passive venting system. To date, results from these data may be summarised as follows:

- Periods of landfill gas efflux into the atmosphere (via the biofilter) alternate with periods of atmospheric air influx into the landfill (via the biofilter). Direction, pressure and rate of gas flux into the biofilter react highly sensitive to the course of atmospheric pressure.Within a stable general weather situation landfill gas emission therefore exhibits a pronounced daily periodicity due to atmospheric pressure changes caused by the periodic alternation of radiation. This dependency is overruled in conditions of unstable weather situation when gas emission reacts promptly to the development of pressure highs and lows.

- The dynamics of gas emission behaviour strongly influence the vertical distribution of methane and oxygen in the biofilter and consequently determine the position and extension of zones where methane oxidation is possible. Passively vented landfills therefore pose specific problems to the design and dimensioning of connected biofilter systems.

Investigations into biofilter performance, biofilter material and the microbiology of methane-oxidation lead to the following results:

- Biofilter performance in 2001 varied between 67 to 100% oxidation of the methane load onto the filter. Expanded clay used as filter material proved suitable regarding gas permeability and distribution, water holding capacity and weathering resistance. Intense colonisation with microorganisms was detected by Scanning Electron Microscopy. A factor that laboratory experiments confirmed to negatively influence methane oxidation is the high salt load of the filter material (maximum electric conductivity of the drainage water reached 14 mS/cm).

- One year following first biofilter operation cell numbers of methane oxidising bacteria have reached 1×10^{11} per g wet weight of filter material, which is four orders of magnitude higher than reported for natural methane-influenced habitats such as marsh soils or rice paddies. The cell numbers exhibit a clear seasonal fluctuation.

- Laboratory experiments regarding methane oxidation kinetics revealed that the methanotrophic population shows a typical Michaelis-Menten saturation function with a maximum methane uptake rate of 1,78 µmol CH_4 h^{-1} g wet weight^{-1} (at 22 °C). Temperature dependence of methane oxidation activity shows the predominance of a mesophilic community with an optimum at 38 °C. However, laboratory experiments revealed that continuous incubation at low temperatures leads to a shift of optimum towards lower temperatures. This is particularly important for biofilter systems which are integrated into the landfill cover material and which are therefore subject to lower temperatures during winter time. Methane oxidation rates doubled with an increase of water tension from -2 to –630 kPa (equals 20 and 3 % water vol/vol, respectively). This means, that even at tensions as high as –630 kPa the filter material chosen provides sufficient water for microbial activity.

- Experimental work in progress concerns the mechanism of oxygen supply to the site of microbial activity. The periodic reversion of gas flow means that O_2 is regularly brought into the system by convection. First results indicate that this mechanism is necessary for methane oxidation activity in the biofilter as diffusion from the atmosphere into the filter is not sufficient to provide for enough oxygen, even at minimal gas flow rates of 0,33 m^3 h^{-1} m^{-3} filter volume. As the reversion of gas flow occurs very quickly, the biofilter is either saturated with methane or with oxygen, intermediary situations are seldom. It must therefore be assumed that the key enzymes are able to load and hold one substrate until the second substrate is available.

References

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