4th Intercontinental Landfill Research Symposium
Gällivare, Sweden

Minutes of session **"Microbial Oxidation of Methane in Landfill Covers and Biofilters"**
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The potential of methanotrophy for the mitigation of low calorific landfill methane emissions receives increasing attention. While in general the factors that influence degradation rates are known, in practical application suitable materials and viable operating conditions for engineered covers and biofilters remain to be evaluated and standardized. In view of this, the session aimed at

- rounding up operational experiences as well as current laboratory and field research on the design and influential factors of engineered systems for the microbial oxidation of landfill methane;
- discussing the applicability of currently available methods for the verification of microbial methane oxidation necessary to satisfy regulatory demands;
- discussing research 'haves and misses' and from that defining the research needed to come closer to the overall goal of reliably implementing engineered methane oxidation systems.

The session was structured as follows (total time 3.5 hrs):

Time [min]	Topic	First author	Title
5			Chair: Welcome & Introduction
15+5	Oxidation: filters	S. Dever	Factors that affect the field performance of passive landfill gas drainage and biofiltration systems
15+5	Oxidation: filters	J. Gebert	Influence of temperature on the activity and microbial community composition in a biofilter used for the oxidation of landfill methane
5+5	Oxidation: filters	R. Haubrichs	**Poster outline**: Biological treatment of poor landfill gas - Evaluation of design parameters for active aerated biofilter systems
5+5	Oxidation: covers	J. Berger	**Poster outline**: Methane oxidation influenced by biochemicals
5+5	Oxidation: covers	B. Adams	**Poster outline**: Assessment of immobilization techniques for methanotrophic bacteria in a biotarp
15+5	Oxidation: covers	T. Abichou	Temporal measurements of methane oxidation in a Florida biocover
15+5	Ox./Emiss. /NMVOC: covers	C. Scheutz	Field measurements of methane emissions and oxidation at a a modern disposal site receiving waste with low organic content
20			Coffee break
70			**Group discussion**
5			Chair: Wrap up

The presentations will be made available to every one by Anders Lagerqvist via the conference homepage.

The group discussion attended to three complexes of **questions**:

Complex I: Factors that influence methane oxidation in the field

Biocovers and biofilters offer different options for the manipulation of factors of influence. While in biocovers factors such as temperature, humidity and methane load mainly depend on the climatic conditions and the gas formation at the particular site, they can be manipulated in (actively operated) biofilters.

1. Are the factors influencing methane oxidation in biofilters and biocovers sufficiently understood? Are there factors of influence that so far have not been addressed (e. g. biochemicals released by plant roots)??
2. Which factors can be manipulated in the field for effective biofilter and biocover performance and how (considering economic viability)?
3. Can we come up with guiding values for a methane load that can be treated by microbial methane oxidation in filters and covers for a given temperature regime?
4. Which questions should be addressed in future research in order to round off the understanding of the factors that govern methane oxidation?

Complex II: Concepts and designs of engineered systems to enhance methane oxidation

Due to the larger areas, for covers the choice of the material will depend largely on availability and cost. In contrast, biofilters are relatively small and contained units and thus to a greater extent allow for selection of materials with specific properties optimal for the application in methane oxidizing systems.

1. Which are the desired biofilter and biocover material properties catering to enhanced methane oxidation rates and which materials possess these properties?
2. Should actively and passively vented biofilters differ with respect to filter layer design?
3. Are we ready to propose a biofilter and a biocover layer design (lots of work done by Marion for covers)?
4. What methods are available to warrant oxygen supply to biofilter and biocover methanotrophs and which one is most effective?
5. What is the perceived potential of cover alternatives such as biotarps?
6. Which questions should be addressed in future research?

Complex III: Methods that enable quantitative verification of methane oxidation in the field

Quantitative proof of methane oxidation is indispensable for acceptance of biological treatment methods by regulators and operators and for possible future participation in carbon credit trading. As biofilters are contained units operated under more or less controlled conditions, a quantification of methane removal is easier than for biocovers.

1. Which currently available method or combination of methods is most effective and viable (economically, labor intensity, data quality) to quantify in situ methane removal by biofilters?
2. Which currently available method or combination of methods (possibly quantitative and qualitative methods) would be most effective and viable to quantify in situ methane oxidation in biocovers?
3. Is it of interest to develop a standardized test protocol for the assessment of the potential methane oxidation capacity of biofilter and biocover material? Which points should be addressed for standardization?
4. Which questions should be addressed in future method-related research?

The three groups working individually on the three complexes of questions came to the following **conclusions**:

Complex I: Factors that influence methane oxidation in the field

1. Are the factors influencing methane oxidation in biofilters and biocovers sufficiently understood? Are there factors of influence that so far have not been addressed (e. g. biochemicals released by plant roots)??

    - The factors influencing the rate of methane degradation such as temperature, moisture, pH etc. in general are well understood. However, the impact of the individual factor depends on the the status of the other factors as well (e. g. the effect of temperature will depend on the moisture status of the material). The effect of the combination of factors which is reality in the field requires more attention.

2. Which factors can be manipulated in the field for effective biofilter and biocover performance and how (considering economic viability)?

    - Biofilters: moisture, temperature, pH, oxygen flux, nutrient supply, porosity of filter material
    - Biocovers: controllable factors are: soil (material) type and permeability, compaction, thickness, vegetation, gas distribution; uncontrollable factors are: climate (temperature and precipitation), methane flux

3. Can we come up with guiding values for a methane load that can be treated by microbial methane oxidation in filters and covers for a given temperature regime?

    - The group agreed that by now many studies exist that have captured the methane oxidation potential of biofilters. Maximum reported values were in the range of 50-80 g h^{-1} m^{-3} under a rather broad range of temperatures from +/- 15 to 50 °C. It would be useful to compile the existing data from the various studies in order to come up with a +/- guiding value for a methane load that can be successfully treated. A prerequisite is the conversion of data according to standardized flux and area/volume units. It was pointed out that the CLEAR-working group is attempting to establish such a database.
    - For biocovers it was concluded that it would be very useful to deduct some guiding values for methane oxidation rates for a range of various uncontrollable factors, such as temperature and moisture. Also, it should be possible to create a document that identifies the range of documented values available from the literature.

4. Which questions should be addressed in future research in order to round off the understanding of the factors that govern methane oxidation?

    - With respect to biofilters, the next step should be the development of best management practises (BMPs) under different conditions of methand flux and climate.

Complex II: Concepts and designs of engineered systems to enhance methane oxidation

1. Which are the desired biofilter and biocover material properties catering to enhanced methane oxidation rates and which materials possess these properties?

   - Balance between porosity and field capacity
   - Different material properties for filter and biocovers
     - Biofilter: performance oriented selection of material
     - Biocover: cost/availability oriented selection of material
   - Mature compost (6-9 months old), problems: material settlement
   - Lack of knowledge with respect to long-term behaviour of materials

2. Should actively and passively vented biofilters differ with respect to filter layer design?

   - A gas distribution layer is most important in biocovers because of the more uneven flux distribution coming from the landfill body.
   - In biofilters, all parameters (such as flux) can be controlled. In addition, the performance-oriented material is most suitable for gas distribution itself. Therefore no special gas distribution layer should be necessary.
   - For biocovers, the upper part should provide good conditions for vegetation. There is no need for vegetation inside an actively vented biofilter.

3. Are we ready to propose a biofilter and a biocover layer design?

   - No, but we would propose a gas distribution layer in a biocover for sure.
   - The design of the upper part of a methane oxidation layer depends on further needs concerning e.g. the limitation of water infiltration to the landfill body.

4. What methods are available to warrant oxygen supply to biofilter and biocover methanotrophs and which one is most effective?

   - For biocovers, at the moment no aeration system is available, but there might be a strong request for creativity.
   - For biofilters, the air can be provided either in front of the filter (dilution of the LFG) or can be directly injected into the filter material.

5. What is the perceived potential of cover alternatives such as biotarps?

   - The group remained sceptic with respect to wether the retention time for methane in a thin biotarp layer would be sufficient to allow for significant methane oxidation.

6. Which questions should be addressed in future research?

   - Influence of vegetation on the temperature und moisture regime
   - Influence of root exudates on methane oxidation capacity (Jan Berger ahs just started on this!)
   - Passive or active aeration systems for biocover or enhancing the availability of oxygen in the material in another (creative) way.

Complex III: Methods that enable quantitative verification of methane oxidation in the field

1. Which currently available method or combination of methods is most effective and viable (economically, labor intensity, data quality) to quantify in situ methane removal by biofilters and biocovers?

    - The group started out with a discussion on how the quantification of methane oxidation in the field is provable. Comparing the emissions before and after implementing a specific measure yields more qualitative data. In order to properly quantify methane oxidation it is necessary to find a method to measure the production of methane in situ. This could be achieved by the baro-pneumatic method which still requires verification. Methane oxidation could then be calculated by collecting emission data from flux chambers and eddy-covariance (shift in CH_4/CO_2 ratio) a well as measuring relative oxidation rates using isotope fractionation. There was doubt if the eddy-covariance method is suitable to determine emissions from compost covers due to increased respiration rates in compost as compared to natural soil. It was concluded that in assessing the applicability of each method the issues of accuracy and reliability of the method need to be addressed.

    - With respect to the quantification of methane oxidation in the field, passively vented biofilters and biocovers are the same, as the differentiation between the two is merely a matter of the surface size. Methane oxidation rates achieved with actively vented filters are much easier to prove as flow meters and concentration measurements can be carried out in the filter supply pipe.

2. Is it of interest to develop a standardized test protocol for the assessment of the potential methane oxidation capacity of biofilter and biocover material? Which points should be addressed for standardization?

    - It was agreed that the development of a standardized protocol to measure methane oxidation capacity would be very useful. Time limits, however, did not allow to go into greater detail…

3. Which questions should be addressed in future method-related research?

    - validation of the baro-pneumatic method to measure gas generation
    - validation of whole-site emission measurement methods