Design of microbial methane oxidation systems for landfills

Julia Gebert[a*], Marion Huber-Humer[b], Alexandre R. Cabral[c]

[a]Delft University of Technology, Faculty of CITG, Department of Geoscience & Engineering, Stevinweg 1, 2628 CN Delft, The Netherlands
[b]Department of Water, Atmosphere and Environment, Institute of Waste Management, University of Natural Resources and Life Sciences Vienna, Vienna, Austria
[c]Université de Sherbrooke, Faculty of Engineering, Department of Civil and Building Engineering, 2500, boul. de l'Université Sherbrooke (Québec), Canada J1K 2R1

[*] corresponding author: Julia Gebert; J.Gebert@tudelft.nl

Supplementary Material 4

Quality control of candidate materials and of MMOS construction

1 Quality control of candidate materials and of MMOS construction

From the previous sections it is obvious that MMOS performance relies heavily on the choice of adequate materials and a handling and construction practice that warrants the intended gas transport and water retention characteristics. This section provides suggestions on key parameters as basis for the practical assessment of the suitability of MMOS materials, recommendations on production, transport and storage of MMOS materials, and on parameters that should be part of the quality control in the field to warrant adequate and harmonized MMOS construction.

1.1 Assessment of suitability of candidate materials

To ensure that the requirements on material properties as explained in section 4.1.3 of the main paper are met, candidate materials should be analysed for the parameters summarized in Table 1.

Table 1: Proposed parameters to be analysed for assessment of suitability of candidate materials. Methods are suggested based on international standards.

Parameter and suggested methods	MOL: Mineral material	MOL: Organic material	FL	GDL
Particle size distribution Method: ISO 11277:2009	x	x	x	x
Standard Proctor compaction curve Method: ASTM D698 - 12e2	x			
Saturated hydraulic conductivity at three compaction levels, e.g. 80%, 85%, 90% of the maximum Proctor density (ρ_{d_max}) Method: ISO 17312:2005	x			
Water retention curve, giving also air capacity[1)] and plant-available field capacity[2)] at three compaction levels, e.g. 80%, 85%, 90% of ρ_{d_max}. Method: ISO 11274:2019	x			
Gas conductivity (k_{Gas}) and effective diffusivity (D_{eff}) at three compaction levels, e.g. 80%, 85%, 90% of ρ_{d_max} ; Method: Poulsen and Blendstrup, 2008; van Verseveld and Gebert, 2020	x	x[3)]	x	x[3)]
Organic matter, as loss on ignition (LOI) or total organic carbon (TOC); Method: ASTM D7348 – 13 or ISO 10694:1995	x	x	x	x
Respiratory activity (oxygen consumption) for organic-rich materials (e.g., composts) or mixtures with these materials; Method: e.g. ISO 16072:2002, CAN/BNQ 0413-220, ÖNORM S2027-4 or German DepV (2009)		x		
NH_4^+ content in materials with high organic matter content (>8 %DM)		x		

Method: ISO 11732:2005				
Carbonate content Method: ISO 10693:1995	x		x	x
Iron fractions Method: ISO 12782-1:2012 and ISO 12782-2:2012	x		x	
pH and electrical conductivity (EC) Method: ISO 10390:1994 and ISO 11265:1994	x	x		

1)Air filled porosity at -6kPa suction,
2) Porosity between -6 kPa and -1500 kPa suction
3)Not compacted, to be tested on material as poured during construction

Determining the CH_4 oxidation potential of candidate materials in the laboratory provides limited informative value, as the material's full potential only develops after exposure to the on-site CH_4 load. It has been shown that exposure of soils to CH_4 leads to the build-up of CH_4 oxidation rates (Ndanga et al., 2016), that in the field CH_4 oxidation rates are related to CH_4 concentrations in the subsoil (Röwer et al., 2011b) and to CH_4 fluxes to the cover (Schroth et al., 2012; Gebert et al., 2016), provided that magnitude of fluxes still enables adequate ingress of atmospheric oxygen.

1.2 Transport and interim storage of selected materials

Just as soils or composts used for landfill covers systems in general, materials selected for use in MMOS (especially MOL material) should be produced, transported, and stored to prevent their pre-compression as pre-compression can influence the materials' mechanical and physical behaviour. This includes minimising the height of storage heaps and preventing saturation of the materials during storage by ensuring that the materials drain well, or by storing them roofed or under a membrane. If soil is stored uncovered for longer time, it is recommended to vegetate the soil heaps. The more finely-grained the soil, the higher the likelihood of undesired effects due to pre-compression.

The materials should only be transported and worked with when dry or moist but never when very moist or wet. Construction should occur when the water content has been reduced to a level that the soil is semi-solid, meaning that the consistency index $I_c > 1.0$, i.e. the water content should be lower than the soil's plastic limit. When the soil water content leads to $I_c < 0.75$, the soil should be dried before construction.

To prevent formation of horizontal interfaces, the individual layers should preferably be constructed in one lift. After construction, the MMOS should not be overridden with machinery compacting the soil beyond the desired extent. To prevent erosion of the newly constructed system, MMOS should be vegetated as soon as possible.

1.3 Test pad and construction of the MMOS

It is recommended to test the materials and construction methods by building a test pad prior to the construction of the actual MMOS to verify that the intended gas transport and water retention requirements are met. Usually, test pads have dimensions as follows: three to four times the width of the compactor and approximately five times its length. Only the central area of this test pad, not affected by acceleration, deceleration, and changes in direction is to be assessed. The results can then be used to adapt construction practice of the MMOS. It is suggested to analyse the test pad and the final MMOS for the parameters given in Table 2.

The sampling scheme should ensure representative samples over the test field and final MMOS area and depth. Proper documentation during the entire construction phase is recommended.

Table 2: Proposed parameters to be analysed for assessment of the test pad and quality of the final MMOS construction, methane oxidation layer (MOL). Methods are suggested based on international standards.

Parameter and suggested methods	Test field	Final MMOS
Bulk density, degree of compaction[1)] Field: Collection of undisturbed samples (ASTM D1587/D1587M) in combination with Laboratory: ISO 11272:2017. Also used in the field: Nuclear gauge (fast; ASTM 2015a), sand-cone (slow; ASTM 2007), or volumetric balloon procedure (slow; ASTM 2015b).	x	x
Water content Method: ISO 16586:2003	x	x
Air capacity[2)] Method: ISO 11274:2019	x	x
Plant available field capacity[3)] Method: ISO 11274:2019	x	x
Hydraulic conductivity Method field: ASTM 5126. Alternatively, it is recommended to use apparatus such as the Guelph permeameter or the Mini Disk infiltrometer (Meter Co.) Method lab: ISO 17312:2005	x	x

[1)]Requires obtainment of the Std. Proctor curve and ρ_{d_max}
[2)]Air filled porosity at -6kPa suction
[3)]Porosity between -6 kPa and -1500 kPa suction (pore pressure)

Sources

ASTM D5126 - 16e1. Standard Guide for Comparison of Field Methods for Determining Hydraulic Conductivity in Vadose Zone.

ASTM D698 - 12e2. Standard Test Methods for Laboratory Compaction Characteristics of Soil Using Standard Effort. ASTM Volume 04.08 Soil and Rock (I): D420 – D5876.

ASTM D7348 – 13. Standard Test Methods for Loss on Ignition (LOI) of Solid Combustion Residues. ASTM Volume 05.06 Gaseous Fuels; Coal and Coke; Catalysts; Bioenergy and Industrial Chemicals from Biomass.

CAN/BNQ 0413-220, 2016. Organic soil conditioners – Composts – Determination of Respiration Rate – Part I: Respirometric Method – Part II: Modified Biochemical Oxygen Demand (BOD) Respiration Method. Quebec, Canada.

DepV – Deponieverordnung, 2009. Verordnung über Deponien und Langzeitlager, vom 27.04.2009 (BGBl. I, Nr. 22, S. 900), zuletzt geändert durch Artikel 2 der Verordnung vom 30. Juni 2020 (BGBl. I Nr. 32, S. 1533)

ISO 10390:1994. Soil quality — Determination of pH.

ISO 10693:1995. Soil quality — Determination of carbonate content — Volumetric method.

ISO 10694:1995. Soil quality — Determination of organic and total carbon after dry combustion (elementary analysis).

ISO 11265:1994. Soil quality — Determination of the specific electrical conductivity.

ISO 11272:2017. Soil quality — Determination of dry bulk density.

ISO 11274:2019. Soil quality — Determination of the water-retention characteristic — Laboratory methods.

ISO 11277:2009. Soil quality — Determination of particle size distribution in mineral soil material — Method by sieving and sedimentation.

ISO 12782-1:2012. Soil quality — Parameters for geochemical modelling of leaching and speciation of constituents in soils and materials — Part 1: Extraction of amorphous iron oxides and hydroxides with ascorbic acid.

ISO 12782-2:2012. Soil quality — Parameters for geochemical modelling of leaching and speciation of constituents in soils and materials — Part 2: Extraction of crystalline iron oxides and hydroxides with dithionite.

ISO 16072:2002. Soil quality — Laboratory methods for determination of microbial soil respiration.

ISO 16586:2003. Soil quality — Determination of soil water content as a volume fraction on the basis of known dry bulk density — Gravimetric method.

ISO 17312:2005. Soil quality — Determination of hydraulic conductivity of saturated porous materials using a rigid-wall permeameter.

ISO 17892-12:2018. Geotechnical investigation and testing — Laboratory testing of soil — Part 12: Determination of liquid and plastic limits.

ÖNORM S 2027-4:2012 06 01. Beurteilung von Abfällen aus der mechanisch-biologischen Behandlung - Teil 4: Stabilitätsparameter - Atmungsaktivität (AT4).

Poulsen, T.G., Blendstrup, H., 2008. Predicting air permeability in porous media with variable structure, bulk density, and water content. Vadose Zone J. 7(4), 1269-1275.

van Verseveld, C., Gebert, J., 2020. Effect of compaction and soil moisture on the permeability of sands for use in methane oxidation systems. Waste Manag. 105, 44-53.