1 Techniques applicable to biological treatments

Encapsulation with semipermeable membrane covers

Description
Encapsulated, positively aerated installations covered and sealed with semipermeable membrane covers are a common method of treating and controlling emissions, such as odours, bioaerosols, dust, ammonia, VOCs as well as greenhouse gases from an active composting heap. In opposition to the known end of pipe means these systems realize the emission abatement at the point of source. The cover is formed by a heavy duty textile laminate with the membrane as the middle layer acting as the functional component while face and back fabric account for the mechanical integrity during handling operations. The emission abatement is based on the phenomena that an aqueous condensate film is continuously generated on the inner surface of the cover which acts like a scrubber dissolving the majority of the gaseous substances as well as trapping particulate matter in combination with the semipermeable behaviour of the membrane.
Following the force of gravity droplets are formed which drip off thus a steady exchange with unsaturated water is kept up ensuring the odour retention capability.

The design of an installation in which a semipermeable membrane cover is used has to be tuned so that the cover is sealed to the installation interfaces to facilitate a slight backpressure and to ensure the exhaust air passage through the membrane. The backpressure provides for a homogenous air supply in the heap formation to facilitate good biological treatment processes.
The water repellency as well as the air and moisture transmission characteristics of the laminate avoid water logging or too rapid drying out of the input material.

Encapsulation with semipermeable membrane covers and laminates can be realized by different designs according to the needs with regards to the siting of a plant. The following listing describes a representative design spectrum:

1. Designs requiring devices to move a cover:
    a. *Heap version with cover sealed to the ground*
    b. *Sidewall version with cover sealed to the sidewall as well as to the pushwall*
2. Housed designs with semipermeable membrane laminates mounted to a moveable frame construction:
    a. *Butterfly version (pitched roof with two hinged halves connected at the beak which can be opened through turning around the outer resting axis) with common wall*
    b. *Lifting roof version with common wall*
3. Combined designs:
    a. *Closed flexible encapsulation connected to a negatively aerated building*

The designs of versions 2 and 3 require the lifting of the cover/roof to provide trafficability of loading vehicles.
Dimension of Heap - and Sidewall versions (1 a & b) range between 15 m and 50 m in length and 6 m to 8 m in width. The height of a heap should be built up in a range of 2.5 m to 3.5 m.

Sidewall versions are realized with wall heights from 1 m to 1.5 m. Housed versions (2) are of individual designs.

All versions are designed so that all other BAT conclusions with regards to the emissions to water and soil are fulfilled and that the connections between the cover laminate and the installation, like the interfaces between the ground (1 a) or side- and pushwall (1 b) or the common wall (2) to the cover are sealed to avoid bypass streams.

Heap versions (1 a) can be sealed to the ground by loading the framing edge strip of a cover made from a non-permeable material with weights or in the case of Sidewall versions (1 b) utilizing flexible ropes threaded through an eyelet pattern in the edge strip which fix and thus seal the cover edge to the sidewall top
For the other designs (2 & 3) the connection can be designed e.g.

- so that moveable components, like roofs or front doors are equipped with appropriate means like rubber lips or profiles to provide the necessary sealability in the closed state of the installation.
- through a fixation of the cover to a wall while the cover by itself is tailored to build a buffer to compensate for the elevated height difference when lifted.

Achieved environmental benefits

- Low energy consumption: 1.5 – 4 kWh/Mg of input material (depending on design and type of aerobic biological treatment)
- Emission reduction performance without further exchange of media
- No inherent odours generated by the semipermeable membrane cover

The following table describes the emission abatement exemplarily utilizing the cover efficiency which is a relative comparison of the atmosphere underneath and above the cover as well a relative comparison to a so called baseline factor which is a standardized emission for an emission type from an open non - aerated compost windrow.

Table 1: Emission abatement as Cover Efficiency and vs Baseline Factor of GORE® Heap Cover using GORE® ePTFE membrane (cited numbers refer to the listed reference literature)

Emission type	Cover Efficiency	vs Baseline Factor
Odour	90% - 97%[2)5)**]	
Bioaerosols	99.99%[2)**]	
Dust/ particulate matter ***	99.99…%*** (undetectable)	
Ammonia		80%[3)*]
VOCs	90% - 95% +****	90% - 98%****

* Input: BioSolids/Sewage Sludge

** Input: Biowaste

*** PM 2.5 Particle Filtration efficiency acc. to "VDI 3926, Part 2 Testing of Filter Media for Cleanable Filters under Operational Conditions from December 1994". This test had been carried out on GORE® L3650 which is a Dry Filtration Media with an ePTFE membrane with a much wider porous structure. This is only for indication purposes. The performance of the GORE® ePTFE membrane of GORE® Heap Cover is supposedly much better due to the tighter pore structure as well as to the fact that a dry filtration test represents a worst case scenario. The trapping effect of the aqueous condensate film for fine particles cannot be considered with this test.

**** Measurements with different input materials in the framework of a project to prove GORE® Heap Cover as BACT (Best Available Control Technology) acc. to SJVAPCD (San Joaquin Valley Air Pollution Control District; CA) Rule 4565 and Rule 4566 and SCAQMD (Southern California Air Quality Management District; CA) Rule 1133.

In the framework of a study carried out by Barth & Bitter; Gutachter im Arbeits- und Umweltschutz GmbH (Consultant for health and safety and environmental protection)[4)] the performance of encapsulation with semipermeable membrane covers, in the respective case design version 2 b, achieved similar or better odour control to conventional tunnel composting systems with biofilter and subsequent maturation for a site with an annual capacitiy of 60 k Mg of a mixed waste input of 70% biowaste/30% greenwaste.

Based on studies M. Kühner states as well that in the framework of the investigation of biowaste composting processes, semipermeable membrane cover "(it) proved that with the use of the membrane a 97 % reduction of the odour concentration can be achieved. The determined average odour load lies with 1.1 OU/m³ Input·s near the emission of a properly functioning biofilter with 0.9 OU/m³ Input·s. Compared with this result an open windrow composting has emissions of an average of 52 OU/m³ Input·s during the first three weeks of decomposition.
Compared with enclosed plants the efficiency of the membrane covering for the total odour load was in a similar dimension like the specific exhaust air collection and purification with a biofilter."[2)]

In the framework of a greenhouse gas study by UBA (Umweltbundesamt Germany)[1)] C. Cuhls et al. asserted that static composting with positive aeration using a semipermeable membrane cover has the lowest emission rate compared to the other technologies treating biowaste. The use of membrane technology reduced emissions from an industry average of 47 kg per tonne to 12 kg per ton (as CO_2 equivalent). The measurements had been determined for a complete heap design (1 a).

Cross-media effects
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Operational data
The capacity range in which encapsulation with semipermeable membrane covers had been realized starts from 2,000 Mg/a up to 200,000 Mg/y. Roughly 200 sites installed over the course of the last 20 years in EU.

Applicability
Applicable to all biological treatments

- Composting
  - Seperated Organic Waste (Biowaste)
  - Biosolids/Sewage Sludge
  - Digestate
- Municipal Solid Waste
  - Biodrying (RDF)
  - Biostabilzation before landfill

Economics

Designs for the encapsulation with semipermeable membrane covers, specifically versions 1 a & b, usually have relatively low capital and operational costs compared to building designs. Considering the emission abatement performance no depletion of any media occurs since no chemical or biochemical processes with involvement of the cover materials take place. The focus here is on conserving the integrity of the cover laminate which consists of the membrane plus back - and face fabric. This is secured through good practice as well as utilizing the appropriate handling devices for designs which require moving the cover for opening and closing of the encapsulated reactor (1 a & b). The designs in which the laminate is mounted to a frame the risk of damage is by the nature of the design unlikely.
E.g. experience with semipermeable membrane covers show when applying best practice average service life times of around 5 - 7 years.

Driving force for implementation

- Design versions 1 a & b are licensable in the federal states of Hesse and North Rhine-Westphalia; Germany with the provision to prove equal or better performance compared to a building system
- Simple and robust technology
- Significantly lower capital costs for Heap - and Sidewall versions[2)] compared to conventional building technologies
- Low maintenance and operational costs
- No end – of – pipe technology necessary except for the design version 3a
- Highest eco efficiency index of the technique (relating to design version 1 & b) in the treatment of separated organic biowaste compared to other biowaste treatment options installed in the federal state of Bavaria, Germany.[6)]

Example plants

A list of reference sites has been submitted to the EIPPC Bureau via the ECN - coalition for biological waste treatment.

Reference literature

1. C. Cuhls et al. (2010); Bioabfallverwertung - *Handbuch Emissionsarmer Anlagenbetrieb. Studie der GEWITRA Ingenieurgesellschaft für Wissenstransfer mbH imAuftrag der Bundesgütegemeinschaft Kompost e.V.*
2. M. Kühner et al.(2001); *Biowaste Composting – New Developments and solutions for the* reduction *of odour emissions – Composting under semi-permeable laminate covers*; HLUG (Hessisches Landesamt für Umwelt und Geologie)
3. Charles E. Schmid (2009); *Whitepaper: Composting trials evaluate VOC emissions control;* BioCycle International Conference 2009
4. G. Bruyn (2011); Expert´s opinion concerning the odouremissions and immissions of different composting systems5. California
5. M. Kühner et al. (2000) "Kompostierung unter semipermeablen Planenabdeckungen als emissionsarems "Low-Tech" und "Low-Cost" Verfahren" (composting under semipermeable membrane covers as low emitting "low-tech" and "low-cost" technology). This research project AZ 08776 had been funded by the German Environmental Foundation. The grant receiver was the Institute for urban water supply and sanitation, water quality management and solid waste management of the University of Stuttgart (Institut für Sidlungswasserbau, Wassergüte- und Abfallwirtschaft der Universität Stuttgart).

6. Rene Peche, Thorsten Pitschke (2014), *Project - Amendment 530556 to the bifa – Text Nr. 61 " Ökoeffizienzpotentiale bei der Behandlung von Bioabfällen in Bayern" (eco efficiency potentials of the treatment of biowaste in the federal state of Bavaria, Germany)*