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THE RAPID DEVELOPMENT OF BIOFILTRATION FOR THE PURIFICATION OF VARIOUS WASTE GAS STREAMS

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SUMMARY

Biofiltration is a new and relatively cheap waste gas purification technique. A very attractive aspect of biofiltration is the high removal efficiency for many odorous compounds. Due to a new filter material, consisting of compost and bark, much higher surface loads are now possible; in a number of situations a surface load as high as 500 $m^3/m^2/h$ can be applied with good removal efficiency and a low pressure drop. The degradation of toluene, aldehydes and ammonia are discussed in detail.
As a result of the recent developments, we anticipate a large increase in the field of application for biofiltration.

1. INTRODUCTION

Biofiltration is a relatively new technique for the purification of polluted air emitted by industry. The first application of this technique on a practical scale, however, took place twenty-five years ago. The area to which the technique was applied, experienced a rapid increase several years ago. At the present moment more than a hundred installations are in operation, principally for the purification of airflows with relatively low concentrations of highly odorous compounds, such as those produced by sewage-water purification installations and rendering plants.

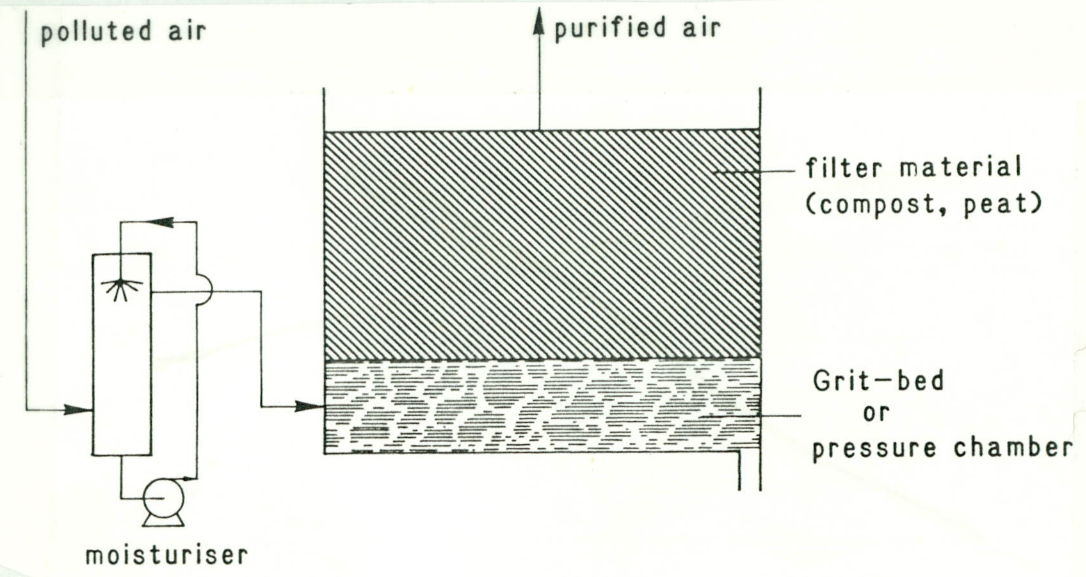

Figure 1. Constructional principles of a biofilter

Figure 1 is illustrative of the construction of a biofilter. The polluted air is conducted through a layer of biological material, approximately 0.5 to 1.0 m thick. At the present time peat mixtures and compost are used as filter materials. An essential for great microbial activity is a sufficiently high moisture content of the filter material (25-50%). In order to prevent the filter from drying out, it is recommended to moisturize the waste gas flow to be cleaned rather than to spray the filter from above. An as homogeneous as possible distribution of the moisture over the surface and the height of the filter are of importance for a good operation.

In those cases where biofilters are located in the open air, which is not exceptional for that matter, further care must be taken to provide for a good water drainage system in consideration of the rainfall. A good distribution of air over the surface can be achieved by a pressure chamber under the filter bed. Here the filter comprises a concrete container in which a floor with slot-like openings is arranged at a height of approximately 50 cm from the bottom of the container. This floor accommodates a supporting fabric thereon, on which in turn the bed of the biologically-active material rests.
It is advised that large biofilters should be constructed in such a manner that they include two or three separate bed-sections. With such an arrangement the other section(s) can remain in operation, in the event of breakdown or maintenance of one of the sections, with a temporarily higher loading imposed thereon.

Several companies deliver installations with double or triple layers. In cooperation with our organisation, Comprimo (Amsterdam, the Netherlands) produces filters built up of stacking modules of 5 - 10 m^2 (see figure 2). Each of these modules cleans an equal part of the totale waste gas flow. When the waste gas temperature is above 40 °C, the gas should be cooled before passing through the biofilter bed. In the case of high concentrations of dust in the waste gas, the latter should be subjected first to a dedusting treatment. When waste-gas flows strongly vary in composition and quantity, biofiltration is less suitable for application as a purification technique.

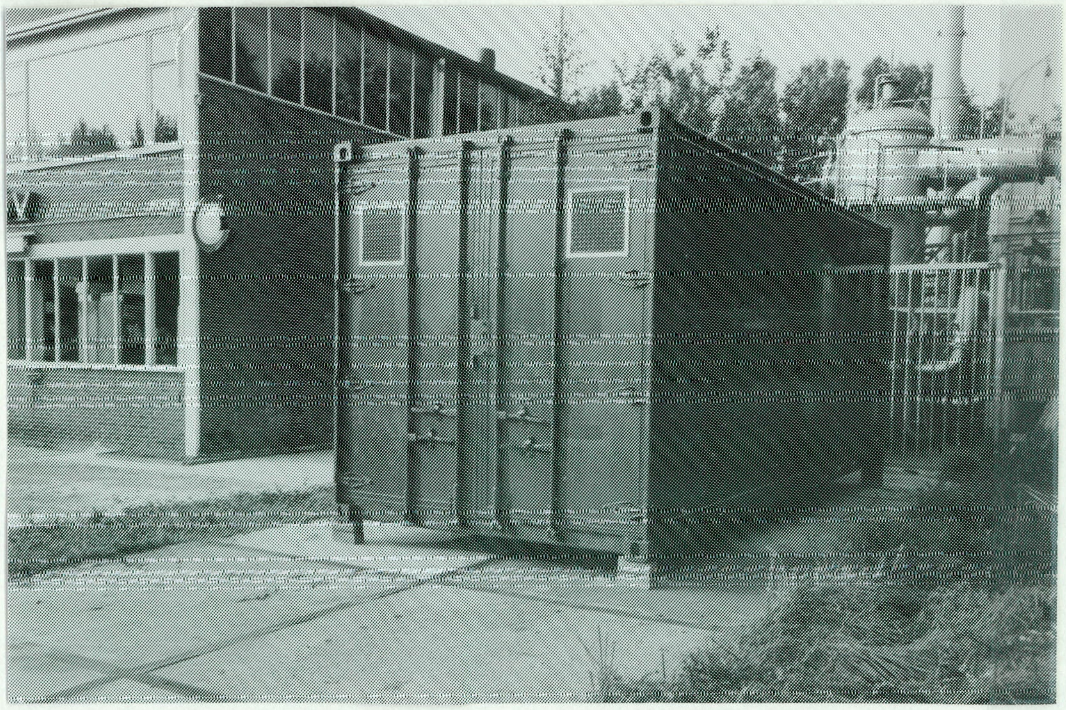

Figure 2. A Biofilter Module

In relation to other techniques employed, biofiltration has the advantage of eliminating many odorous and chemically very different compounds with a high degree of efficiency. This is due to the fact that the micro-organism population has adapted itself to compounds present in the waste-gas flow. Biofiltration is to be considered to be a very cheap air-cleaning technique, as appears from data published earlier by us /1/.

2. DEVELOPMENT OF FILTER MATERIALS WITH A LOW RESISTANCE TO FLOW

Conventional biofilters occupy relatively large areas. A maximum surface loading figure of 5-10 $m^3/m^2/h$ was obtained with the first installations. This means that a filter of 100 m^2 or more is needed for the purification of a throughput of 1000 m^3/h.
Alteration of the filter material has led to an increase in the applicable surface loading to approximately 35 $m^3/m^2/h$ in the case of sewage water purification installations, while in the case of rendering plants filters have been installed with a surface loading in the order of 100-150 $m^3/m^2/h$.

With the application of compost the limiting factor for the permissible surface loading is often the pressure drop across the filter. Then, in the case of a rendering plant, it is possible in principle to increase the surface loading figure to 500 $m^3/m^2/h$, because the purification yield still amounts to more than 98%. The pressure drop then, however, will increase to 10,000 Pa (1000 mm water column). Reduction of the pressure drop by decreasing the thickness of the filter material layer down to 20 cm for example, appears hardly feasible in practice, due to inhomogeneities in the compost bed itself, as a result of which air escapes through the filter without having been treated.

We have carried out an investigation into the optimization of the compost bed in the interest of reducing the resistance to flow. By modifying the particle-size distribution, a material has been developed with an about 10 times lower resistance to flow. An essential of this product is that a fairly fine and active fraction from the compost is mixed with coarse inactive particles whether they be from compost or not /2/.

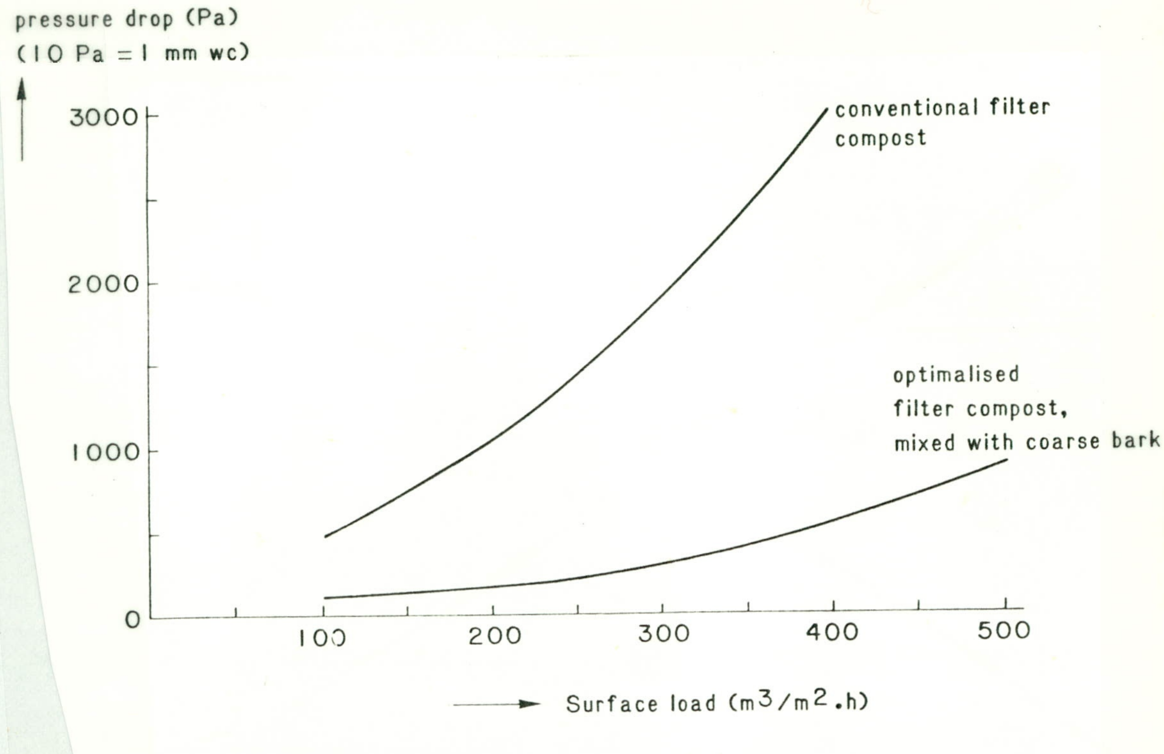

Fig. 3. Pressure drop across a biofilter with several filter materials (bed height = 1 m)

Figure 3 shows the course taken by the pressure drop for conventional filter compost and a mixture of fine compost particles and coarse bark particles. Due to further development work, together with Nederlandse Vuil Afvoer Maatschappij N.V. (VAM, the Dutch Waste Disposal Company), the optimalised filter material is now produced on a large scale. In a 5 m^3 pilot-plant installation the material proved to have a good stability: the pressure drop after an operational period of one year at 300 $m^3/m^2/h$ and a bed height of 1 m was not higher than 45 mm wc. By applying this filter material, the treatment costs of polluted air by means of biofiltration have been reduced by approximately 50%, while the installation size has been reduced to one third of its original dimensions through a higher surface loading. At the moment four industrial installations are in operation with good results. Another five will follow soon.

Alongside compost-based filter materials, there are, for example, filters filled with peat mixed with materials, such as spruce-fir branches or heather. The pressure drop experienced with these types of filter material is comparable with that of optimalised compost. When peat-based filter materials are used, the surface loading cannot be increased too much in a considerable number of cases, due to the decrease in the efficiency of removal.

3. OPTIMALISATION OF THE DEGRADATION CAPACITY

Increasing the surface loading is subjected to certain limitations; above a certain limiting value the purification efficiency will decrease. In this context the results of our investigation into the degradation of a number of components (a.o. toluene, ammonia and aldehydes) in biofilters can be mentioned. The experiments were carried out on a pilot-plant scale with perspex columns with a height of 1.0 m and a diameter of 0.5 m.

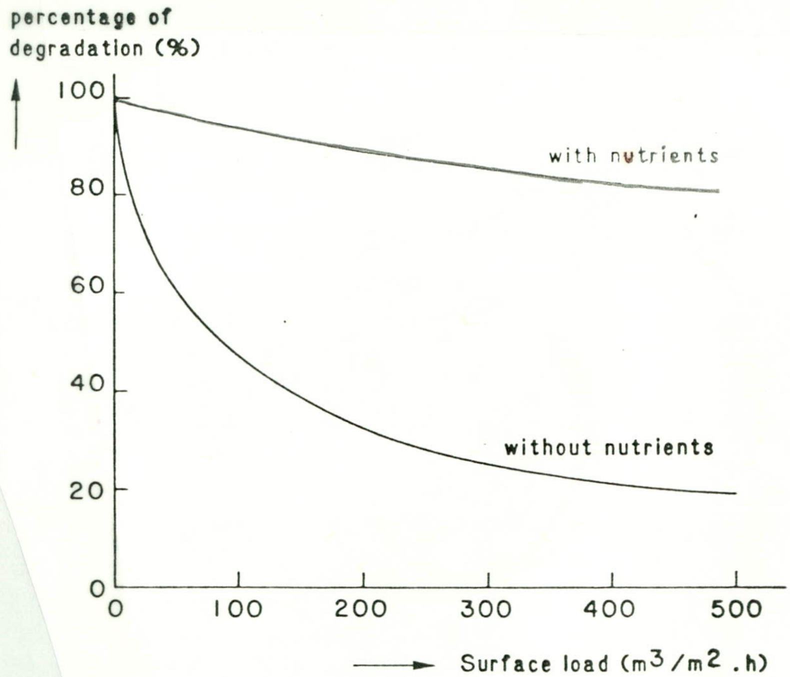

Fig. 4. Degradation of toluene in a biofilter with and without adding nutrients ; the concentration of toluene is 100 mg/m^3

Curve 1 in Figure 4 shows the course taken by the extracted yield as a function of the surface loading in the purification of a waste-gas flow contaminated with toluene in a compost filter. To obtain a 90% degradation efficiency, the surface load must not exceed 25 $m^3/m^2/h$. By adding inorganic nutrients the degradation can be enhanced drastically, as is shown by curve 2 in figure .4 More detailed information on toluene is discussed in /3/, where the influence of temperature and oxygen pressure is also reported.

4. REMOVAL OF AMMONIA FROM WASTE GAS STREAMS

Ammonia is an important component of a lot of odorous waste gas streams, e.g. the ventilation of intensive cattle breeding facilities, manure handling and waste composting. Apart from odour abatement, the removal of ammonia is also important due to its contribution to soil acidification by deposition from air. Abatement of ammonia emissions from pig and chicken houses should eliminate an important source.

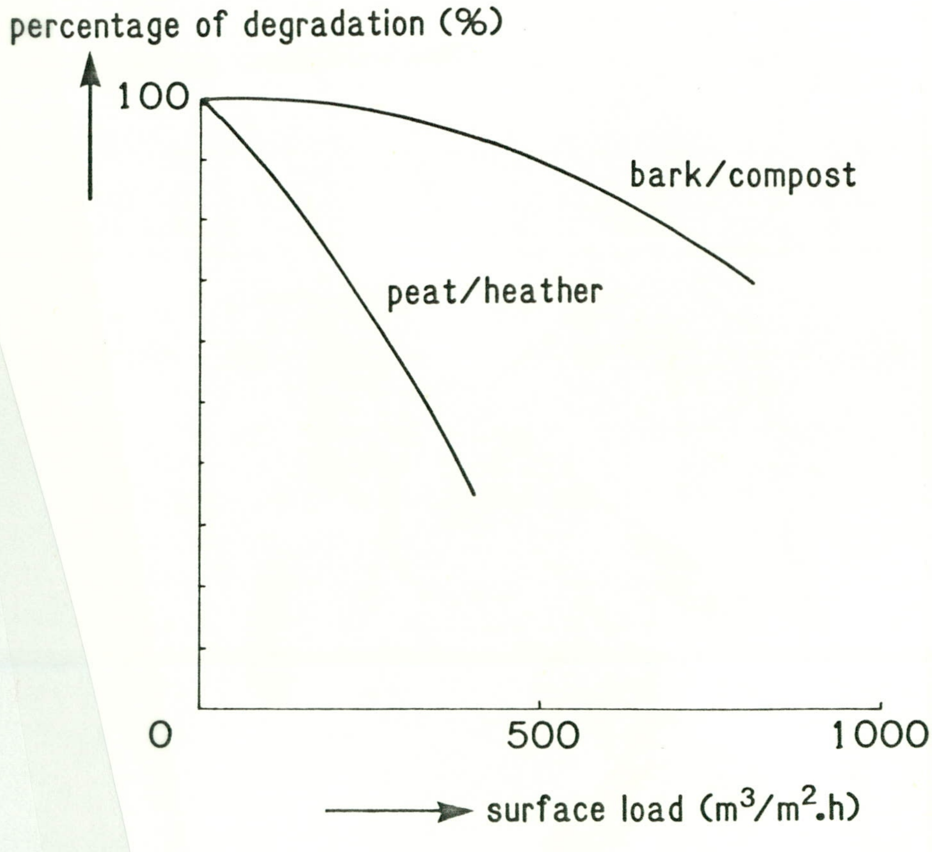

Fig. 5. The degradation of ammonia in a biofilter

($5mg\ NH_3/m^3$, 20^oC, bed height 1 m)

Figure 5 shows the curves for degradation of ammonia in laboratory filter installations with bark/compost and peat/heather. At a concentration level of 5 mg NH_3/m^3 the removal efficiency in the bark/compost filter is significantly better than compared to the peat/heather filter. A remarkable observation in our search is the self-buffering degradation course. The ammonia is converted for about 50% to nitrate; the other half remains in the filter as ammonium. The equilibrium pH value amounts to about 6. At this value the absorption of the alkaline ammonia compensates the microbial production of acid due to ammonia oxidation (nitrification). The study also revealed another feature of ammonia degradation in biofilters. It appeared that at a concentration level of more than 50 mg NH_3/m^3 the removal efficiency dropped drastically after a few days' operation. This was caused by toxification. Several toxicity tests confirmed this explanation. This effect has to be ascribed in principle to ammonium. The nitrate concentration can increase to about 60 g/l, without the activity decreasing.

Subsequent pilot-plant filters installed at a pig house and a chicken farm confirmed the observations indicated above. A surface load of about 400 $m^3/m^2/h$ seems applicable at a bed height of 0.5 m of bark/compost, resulting in an NH_3-removal efficiency of 90%.

5. MICROBIAL ADAPTATION C.Q. INOCULATION

The degradation of synthetic components in biofilters gives problems in a number of cases. Special starting-up procedures or inoculation with active sludge in order to add special micro-organisms prove to be very fruitful. We can mention, for example, our experiences with an aldehydes-containing waste gas. Starting up the biofilter with a low surface load (10 $m^3/m^2/h$, about 3 g aldehydes/m^3) did not result in any purification of the gas; even after a period of operation equal to six months, the removal efficiency remained zero. However, starting up with 30-fold diluted waste gas and subsequent stepwise diminishing of the dilution ratio revealed a degradation capacity of 40 g $C/m^3/h$ after four months (see figure 6). In a later experiment we inoculated the filter material with active sludge from a selected water purification plant of a factory with aldehydes-containing waste water. After a period of only two weeks a degradation capacity of 40 g $C/m^3/h$ was found here.

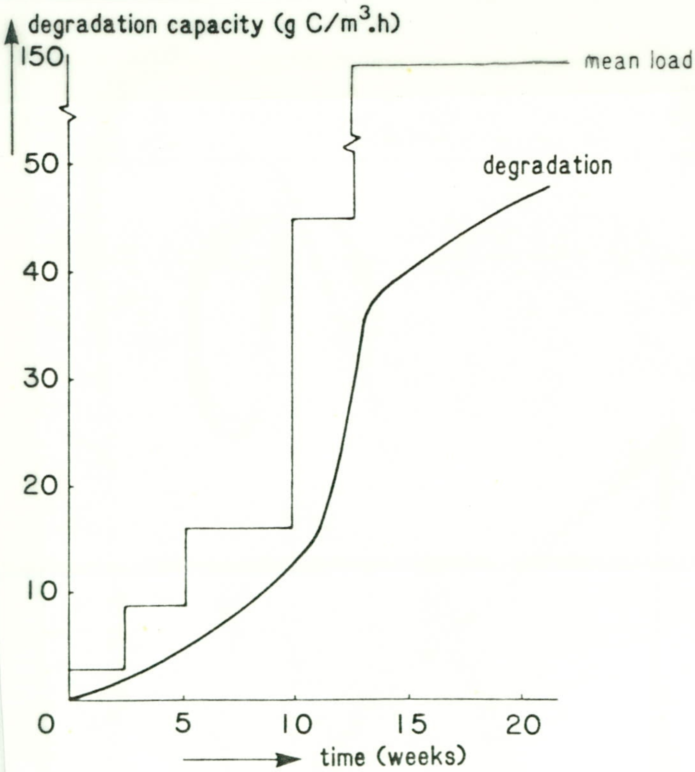

Fig. 6. The degradation of aldehydes in a biofilter at a constant surface load of 50 $m^3/m^2.h$;
Start - up with 30 - fold diluted waste - gas, followed by stepwise diminishing of the dillution ratio

With reference to the abovementioned experiences we have made a survey of water purification plants in the Netherlands and the components degraded there. On the basis of this survey we can select potentially suited active sludges for inoculation of a biofilter for the removal of specific components out of a waste gas.
We are also developing special microbial activity tests for the optimalization of biofilter conditions by rapid experiments on a small scale. This research is directed at the degradation of acrylates, fenoles and mercaptans.

6. APPLICATION FIELD OF BIOFILTRATION

At the present time biofiltration is successfully applied in the Netherlands in a rapidly increasing number of locations. After filters have been installed at rendering plants and sewage-water purification establisments, they are now also being used by a fat-rendering plant, an oriental-cuisine product factory, several slaughterhouses, a factory for the processing of chicken-feathers, a seed-oil processing company, a manure-drying plant and a plant for pellet-pressing of ground-rendering products. Within a short time this technique will be applied in a compost-producing installation and the cattle-feed industry. Further extension of these and other industrial activities can be expected. In /3/ the application field of biofiltration is discussed more extensively on the basis of a summary of the industrial activities with a strong potential for odour nuisance.

As a conclusion of this paper we pose that the perspectives of biofiltration are very good. A more widespread application can be foreseen. This positive perspective can be enhanced by taking process-integrated measures to diminish waste gas flows. As an illustration of this point we can finally mention our investigations at coolers for pressed cattle-feed: through process changes 90% of the odour-emission could be concentrated here in 50% of the original waste gas flow. As a result the required biofilter size halved.

ACKNOWLEDGEMENTS AND COMMENTS

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