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THERMOPHILIC BIOLOGICAL TREATMENT OF HOT WASTE GASES

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Until a few years ago, the assumption was made that the possibilities of biological treatment of waste gases were limited to air flows with a temperature between 15 en 40°C. However, during the last 15 years it emerged that biological waste gas treatment techniques, such as biofiltration and biotrickling filtration, can be successfully applied to hot air flows. Once more the microorganisms surprise us with their unrestrained flexibility.

Hot waste gases

For various processes which include boiling, drying, sanitization or other thermal treatment of organic material, a formed waste gas loaded with odour has to be treated. This includes for example food processing and rendering facilities, sludge drying installations, grain extruders, oil mills, etc. Furthermore, hot waste gases can arise from the thermal treatment of textile (for example backing of carpet) and from specific chemical processes. Because of the high odour or solvent load, these gas flows require treatment prior to discharge into the atmosphere.

Sometimes incineration techniques are not economically viable as treatment technique because of the minor concentrations of pollutants in these air flows. In these cases, the waste gas flows are mostly first cooled by heat exchangers or by mixing with fresh air.
This way, these air flows are treatable by conventional waste gas treatment techniques (biofiltration, adsorption, scrubbing,…). Application of heat recuperation is in actual practice not always economically feasible (due to dust and grease). As a result, until recently, the most preferred option was to dilute these hot waste gases. Due to this dilution with fresh air, a much bigger air flow had to be treated. For example, a hot air flow of 10 000 m³/h (85°C, 35% RH) had to be mixed with 20 000 m³/h of fresh air (20°C, 60% RH) in order to obtain a mixed stream with a wet bulb temperature of 37°C. If this air needs to be treated by conventional biofiltration, this cooling by dilution represents a tripling of the required reactor volume and consequently a considerable increase of the investment cost and required space.

During the past 15 years, evidence has been gathered that proofs the viability of biological treatment of hot waste gases without preliminary cooling, in particular with thermophilic biological waste gas treatment. Over the past few years, Trevi also successfully realised various thermophilic biological waste gas treatment installations according to this concept.

Thermophilic microorganisms (thermophiles)

Figure 1 describes the microbiological activity of various groups of microorganisms in function of the temperature. The microorganisms which are active in the conventional biological waste gas treatment installations mostly belong to the mesophilic group (mesophiles) and have an optimal activity at temperatures between 20 and 40°C. In this range, the assumption is often made that the biological activity roughly doubles at a temperature increase of 10°C, until a maximum of 37°C is reached.

At higher temperatures, thermophilic microorganisms can, however, take over the role of their mesophilic colleagues. Thermophiles are microorganisms with an optimal growing temperature higher than 45°C. The maximum temperature for these microorganisms is situated around 70°C. As a result, the possibilities of thermophilic biological waste gas treatment are limited to air flows with a wet bulb temperature lower than 70°C. Note that most of these hot air flows in industries have a low relative humidity and rarely show a wet bulb temperature higher than 70°C. This implies that the temperature of most of these hot air flows can be cooled towards the thermophilic area (40 – 70°C) by simple humidification.

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As shown in Figure 1, microbiological activity at temperatures lower than 10°C is not impossible.

Literature shows successful biological waste gas treatment at air temperatures between 0 and 10°C. This is the scope of psychrophilic microorganisms.

Besides, note the presence of various operational biological waste gas treatment installations in the Scandinavian countries.

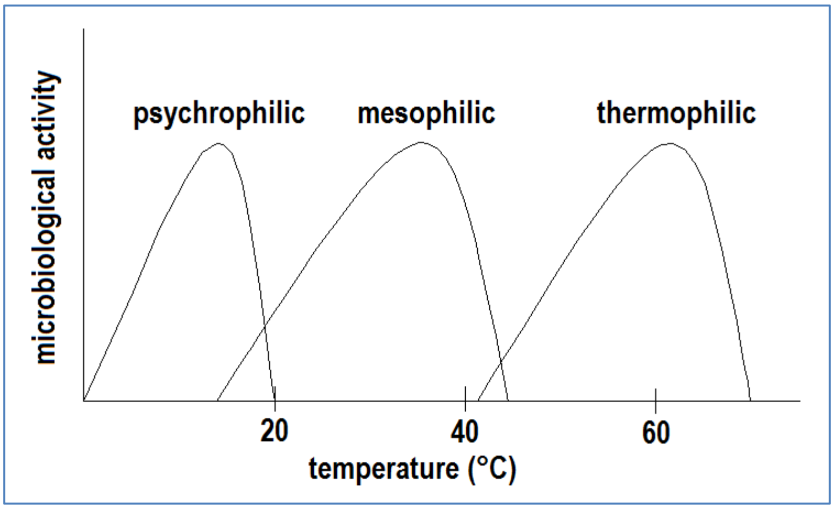

Figure 1. Optimal temperature range for various groups of microorganisms

Thermophilic biological waste gas treatment

Over the past years, thermophilic applications were achieved for biofilters, biotrickling filters and bioscrubbers. Practice shows that for most of the volatile substances (exception: NH_3) a thermophilic microorganism exists, which will quickly develop in the bioreactor. Also for air flows containing solvents (for example benzene and toluene), successful applications are mentioned. Contrary to the mesophilic installations in which the microbiological degradation is established by bacteria, fungi, yeasts or a mixture of these organisms, bacteria dominate in thermophilic reactors.

Thermophilic bioreactors appear to provide a number of important advantages compared to the conventional mesophilic operations. As shown in Table 1, the elimination capacities under thermophilic conditions are mostly higher than under mesophilic conditions. The effect is, however, strongly specific for each pollutant. Therefore the elimination capacity of a biofilter for benzene increases sixfold at thermophilic operation compared to mesophilic operation, while for xylene the elimination capacity is halved. The final effect is determined by the relative importance of the change in microbiological activity in relation to the change in mass transfer at increasing temperature. In most of the cases however, the required reactor volume under thermophilic conditions will be smaller than under mesophilic conditions.

Table 1. Maximum elimination capacity (ECmax) for a number of volatile organic compounds in bioreactors under mesophilic and thermophilic conditions

compound	mesophilic operation EC_{max} (g/m^3.h)	thermophilic operation EC_{max} (g/m^3.h)	reference
BTEX	188	218	Mohammad et al., 2007
methanol	85	120	Kong et al., 2001
α-pinene	35	75	Kong et al., 2001
isobutyraldehyde	97	139	Luvsanjamba, 2008
dimethyl sulfide	75	45	Luvsanjamba, 2008
pentanone	53	63	Luvsanjamba, 2008

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An additional advantage of the thermophilic operation is the smaller accumulation of biomass. Under these conditions, the pressure drop in biological waste gas treatment installations will consequently rise more slowly than under mesophilic conditions. Besides, for the treatment of greasy air flows, grease deposition and blockage will less problematic as under mesophilic conditions.
A current question in the case of thermophilic biological waste gas treatment is the degree of inactivity of the biomass during periods of lower temperature (weekends, time between 2 batch processes). In practice this appears not to be a problem during short periods. Only during longer periods of inactivity (for example after a few weeks of vacation) a temporary lower removal efficiency can be observed.

Obviously there are also a number of points of interest to mention. Under thermophilic conditions, an often faster degradation of biofilter material will occur, so that the lifetime of the biofilter material will be shortened. In addition, much more attention should be paid to keeping the biofilter material sufficiently humid, because of the increasing chance of drying out and preferential channel formation. This phenomenon can be avoided by downflow operation of the biofilter (air from top to bottom). Biotrickling filtration can be selected as an alternative, at which the pumping of a washing liquid over a synthetic carrier material prevents drying out.

Figure 2. Some examples of thermophilic biofilters

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