BIOLOGICAL WASTE GAS CLEANING IN A PILOT-SCALE BIOFILTER WITH DIFFERENT FILTER MATERIAL AND MODELING A HYBRID PROCESS OF ADSORPTION AND BIOFILTRATION

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Summary

Biological waste gas cleaning is gaining more and more importance for the removal of the volatile organic compounds from air polluted streams. In order to investigate the performance of this technology a biofiltration pilot unit was operated for a continuous period of 14 months. The biofilter was packed with newly developed compost pellets and a mixture of compost and peat. At start-up, the biofilter was inoculated with a microbial consortium adapted to degrade ethylacetate. The biofilter was then fed with ethylacetate enriched air. The maximum elimination capacities were 199 g m^{-3} h^{-1} using the compost pellets and 112 g m^{-3} h^{-1} for a mixture of compost and peat. The compost pellets showed no long-term impairment at very high inlet gas concentrations and after periods without pollutants.

Fluctuating concentrations of the contaminants in the waste gas may have a negative influence on the biofilter performance. Therefore it is desirable to buffer the fluctuations in the waste gas. A possibility to achieve this is the incorporation of an adsorber into the process. The complete process of adsorption and biofiltration is modeled using ethylacetate as a model substance in the waste gas. Activated carbon and zeolites were used as adsorbents in a fixed bed. It is shown in this chapter, that the influence of the concentration peak on the biofilter performance is negligible.

1. Introduction

Increasing concern about the environment as well as the ever more stringent national and international regulations have led to the development and optimization of processes aimed at reducing pollution of water, air and soil. There are two strategies to reduce the air pollution. For a comprehensive environmental protection emissions should be avoided by the application of newly developed techniques (clean production). Process optimization and modifications of production processes lead to a reduction of emissions and savings of energy and raw materials. Biological, chemical and physical processes are used to reduce the air pollution after the process (end of pipe).

Most of the waste-gas cleaning processes work at low waste gas concentrations. But even so companies have to reduce emissions due to tougher regulations and critical neighbors. A number of technical tested processes (absorption, adsorption) are available to achieve a reduction of emissions. Biological processes are gaining more and more importance and compete with the conventional processes. When compared with other conventional technologies, the biological processes are found to be more economical (Van Groenestijn and Hesslink 1993) and environmentally viable since they do not produce any secondary water, air or soil pollution, which in turn may need further treatment. Which process is used for a specific air pollution problem depends on economical and technical criteria.

The biofiltration process to clean waste gases has been widely studied (Deshusses 1995, Ottengraf 1986, Shareefdeen 1994). The pollutants molecular structure and it's concentration in the air flow are the most important factors for the biofilter performance. Humidity control to avoid drying or increased sogginess (Auria 1998) and nutrient supply (Morgenroth 1996) have a direct impact on the microbial activity and thus in the overall elimination rates. Materials used for biofiltration processes require a good air permeability to prevent high pressure drops, high specific surface area, good wetting characteristics and good sorptive capacity. The filter material has a great significance for the overall performance of the bioreactor, being the habitat of the microbial communities. The actual state of the art offers different kinds of filter materials: Various compost types, peat, bork or, on the other hand, plastic packings originated from the conventional mass transfer technology. Plastic packings are inert and therefore durable, but require a precisely dosed mineral salt feeding for an efficient microbial metabolism allowing the degradation of the waste gas pollutants. The advantage of the plastic packings consist in their well defined geometric size and their high porosity causing a low pressure drop of the waste gas stream flowing across the bioreactor. Organic materials do not necessitate mineral salt feeding, because they are contained in sufficient amounts in the filter material itself. The main disadvantage of organic packaging materials is the high pressure drop of the waste gas stream across the bioreactor, which even increases in time because of the compressing of the packaging and because of the accumulation of biomass.

Fluctuating concentrations of the contaminants in the waste gas may have a negative influence on the biofilter performance. Temporary high concentrations could be toxic for the microorganisms in the biofilter, resulting in an inactivation of the system. Therefore the fluctuations in the waste gas concentration should be buffered. One possibility is the incorporation of an adsorption step into the process as described.

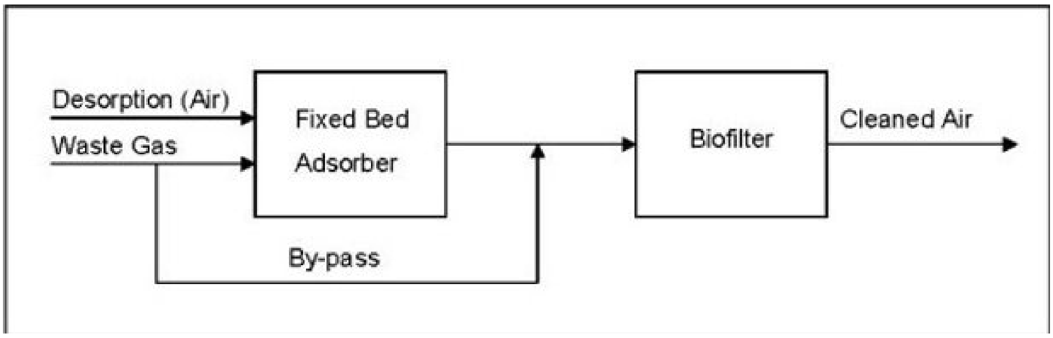

Figure 1: Model hybrid process to buffer concentration peaks

This hybrid process is shown in Fig. 1. It comprises an adsorber where the adsorption takes place at high concentrations and the desorption with air. In the model it is assumed that during the adsorption process the microorganisms are not supplied with nutrients from the waste gas. This should not cause problems if the adsorption does not last for more than 1 to 2 hours. In order to simulate the hybrid process of adsorption and biofiltration each unit was modeled separately.

2. Materials and Methods

Biofiltration unit

The pilot-scale biofilter used in this study is shown in Fig. 2. It consists of different 2 parts. One is the production of the waste gas and the other one the biofilter. The waste gas production consists of a waste gas humidification unit and a loading unit. Here a side stream of air was led through a bottle filled with test solvent ethylacetate. Before entering the biofilter both streams were mixed.

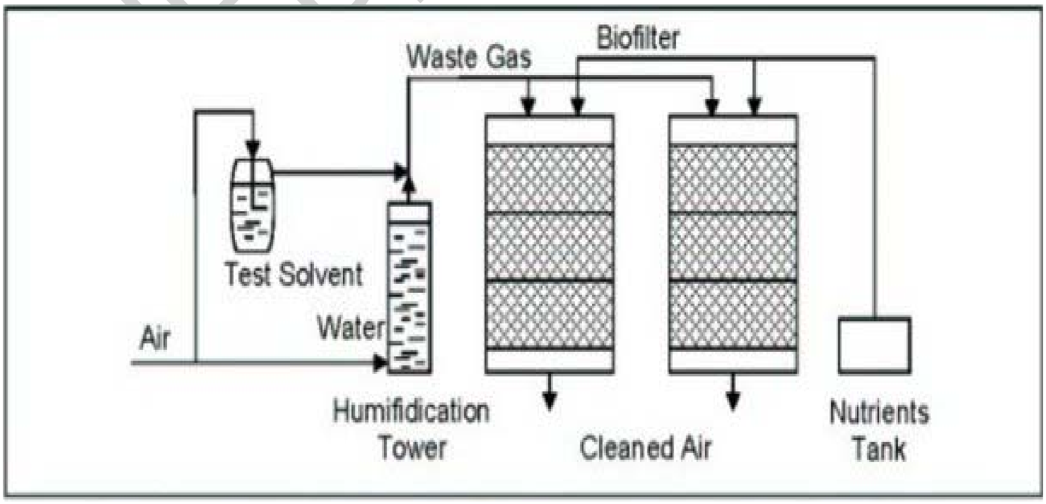

Figure: 2 Pilot-scale biofiltration unit

The waste gas streamed from top to bottom in the biofilter columns. The biofilter had two three stage columns made of rigid Plexiglas. Each biofilter column was 1.5 m high divided into 3 segments of 0.5 m and had an inner diameter of 0.19 m. The filter material was supported on a sieve plate that ensured homogenous distribution of the influent gas across the width of the filter bed. Two different filter materials were tested. One column was filled with a mixture of compost and peat while the other one was filled with compost pellets (Pröll 1995). The compost pellets were produced of compost as the main organic component, a binding material based on aminoplast resin and a suitable hardening agent. In a pellet mill the components were formed into pellets under simultaneous setting of binding material.

A microbial consortium adapted to degrade ethylacetate was originally obtained from an industrial biotrickling filter unit that treats contaminated air from a printing press. This mixed culture was further enriched in a mineral medium.

Adsorption unit

Ethylacetate was used as a model waste gas for the adsorption process. Activated carbon and zeolites were used as adsorbents. The experimental work for the adsorption process consisted of 2 steps. In a first step the adsorption kinetics were measured on single particles with thermogravimetric analysis using a Cahn TG 121 (Fig. 3). Experiments with a fixed bed column followed.

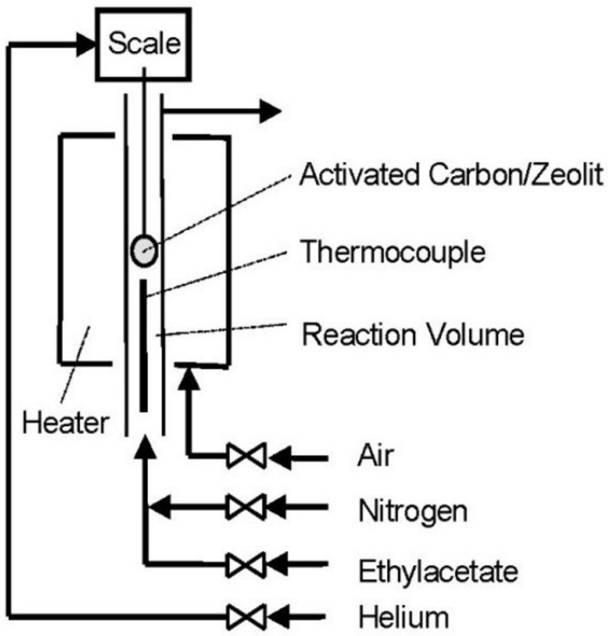

Figure 3: Thermogravimetric analyzer Cahn TG 121

The thermogravimetric analyzer provides a means of measuring weight changes of a sample over a given temperature range under specified environmental conditions. The furnace temperature follows a precise temperature profile. Weight measurements are taken periodically. The balances have a closed loop servo controlled transducer which automatically compensates for weight changes in the sample. The electrical current necessary to return the balance beam to its "null" position is directly proportional to weight. Since this is a null balance, the sample always remains in the constant temperature zone. The adsorbents were regenerated at 130 °C for 30 min before the sorption experiment started.

The apparatus used to measure breakthrough curves consists of two main components. The first part is used to generate the waste gas. The air stream is divided into two parts. One part is led through a bubble column filled with ethylacetate. Both streams are mixed before entering the adsorption column. This is a thermostated column made of rigid perspex with an inner diameter of 20 mm (Fig. 4). The adsorption column was packed with activated carbon or zeolites. Appropriate ancillary equipment was used to control and measure the flowrates and composition of the gas streams accurately.

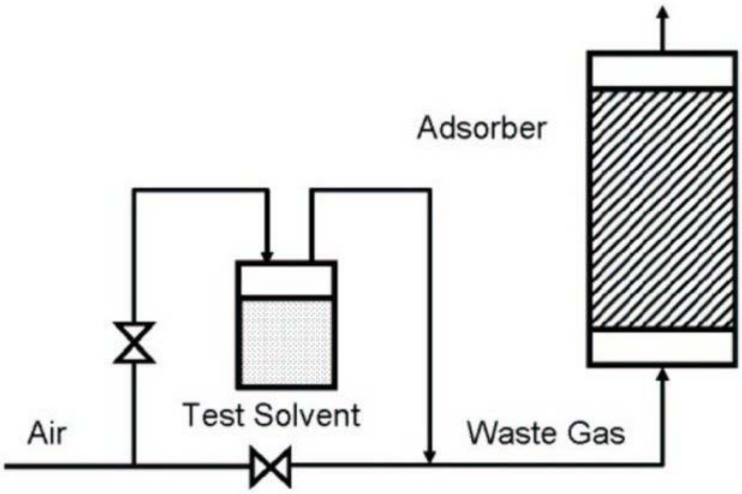

Figure 4: Fixed bed adsorber

As already mentioned activated carbon and zeolites were used as adsorbents. There are a few requirements to be met by adsorbents, like

- High capacity
- High selectivity for components
- Easy regeneration
- Low pressure drop.

A few properties of the adsorbents are displayed in table 1.

	Activated carbon	Zeolite
Manufacturer	Donauchem, Austria	Hüls-Degussa, Germany
Product	Donau Carbon CC90	Wessalith Day F-20
Pore radius	1 nm	0,4 nm
Specific micro pore volume	0,4 cm^3/g	0,3 cm^3/g
Specific surface area	1200 m^2/g	800 m^2/g

Table 1: Properties of adsorbents

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Biographical Sketches

Dr. Jan Paul studied Chemical Engineering at the University of Erlangen-Nuremberg in Germany including one year at the University of Bath / UK and three months at the University of Natal in Durban / South Africa. In his diploma thesis he investigated the cleaning of air polluted from animals using a novel membrane reactor. He obtained the PhD from the University of Technology in Vienna / Austria. His research at the Institute of Chemical Engineering was focused on the development of a hybrid system for cleaning waste gas. The hybrid system consisted of a biofilter unit and an adsorption unit. He than worked for MCE Anlagenbau Austria (formerly Mannesmann) in Vienna / Austria in the R&D department being responsible for the management of research projects including the coordination of an EU project. His work was focused on energy technology and building technology. He is now working for Reichhold as a process engineer serving the European plants of Reichhold. He has published more than 10 papers on biofiltration and energy technology and holds one patent.

Univ.-Prof.Dr. Anton Friedl finished his study of Chemical Engineering at the University of Technology Vienna in Austria 1984. His PhD Thesis focused on the topic “downstream processing during alcohol fermentations” and was finished 1990. Research on the same topic was performed at Massey University in Palmerston North, New Zealand (19989/1990) and University of California in Berkeley (1991). During 1990 till 1996 he was head of the research group “Bioprocess Engineering and Membrane Processes” at the Institute of Chemical Engineering at the University of Technology Vienna in Austria followed by a industrial period in the field of power plant engineering with Austrian Energy & Environment during the time between 1996 and 1999. Since 2000 back to the Institute of Chemical Engineering at the University of Technology Vienna and head of the research area of “Thermal Process Engineering and Simulation” with a staff of about 15 research assistants and projects in the fields of renewable energy and chemical supply supported by process simulation and computational fluid dynamics. He has published more than 100 papers in various basic research as well as applications within chemical engineering.