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BIOFILTRATION OF AIR POLLUTED WITH ETHYLBENZENE**

Results of laboratory bench-scale tests of biofiltration of the air polluted with ethylbenzene are presented. The experiments were carried out in a column filled with a modified peat bed. The relations representing filtration efficiency versus load and filtration rate versus load of the pollutant in the filtration bed are found. Moreover, the time necessary for microorganisms to adapt themselves to increased loads and their susceptibility to the changes of moisture content in the bed were determined.

1. INTRODUCTION

Considerable amounts of organic pollutants emitted to the atmosphere present a challenge to us, hence new methods for reduction of the emission are still appreciated. Among the main sources of air pollution are paint shops, chemical plants, furniture manufactures and other solvent users. For over ten years the biological methods of flue gas purification has competed with the conventional air purification systems.

Biofiltration of flue gas is a complex process of continuous absorption and decomposition of organic air pollutants. Both absorption and decomposition occur simultaneously in the same biologically active bed. Organic pollutants dissolve in water film occupied by heterotrophic bacteria. The so-called "biofilm" is maintained on the surface of supporting bed. It is responsible for the decomposition of organic compounds.

The critical process, that determines the efficiency of biofiltration, is mass transfer through the gas–liquid phase boundary. Both organic compounds and oxygen should be uptaken from flue gas and dissolved in water. In practice, the following requirements should be met [1]:

- organic pollutants should be biodegradable,
- pollutants should be soluble in water or fats,
- temperature of flue gas should not be dangerous for bacteria,
- flue gas components should not be toxic for bacteria,

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- filter bed should be damp,
- filter bed should have an appropriate pH and all mineral nutrients for bacterial flora.

In our previous study [1], material of the filter bed was selected in such a way as to meet the following characteristic requirements: grain size composition providing a suitable porosity, specific surface area and gas-flow resistance, as well as water-holding capacity, stability, availability, costs and maintenance requirements. Suitable materials are [2]:

- peat,
- fertile humus of fluffy structure,
- composted municipal refuse,
- composted bark.

Specific feature of biofilters is their considerable (sometimes rather long) start-up time. Adaptation of the bacterial flora to new organic compounds being introduced takes from 4 to 10 days. Generally, it is assumed that the start-up period is finished when the efficiency of pollutant removal reaches 80–98% [2], [3].

The studies were aimed at determining the possibility of applying biofiltration in the removal of ethylbenzene from flue gas. Ethylbenzene being a constituent of many industrial solvents is one of the most commonly encountered air pollutants. The experiments were carried out with easily available and not expensive filter bed material – mixture of garden peat, activated sludge prepared in laboratory and molasse. Very low water solubility [4] and poor biodegradability [5] of ethylbenzene are considered to be main obstacles of the process.

2. METHODS

2.1. BIOFILTER

For block diagram of the laboratory-scale biofilter system see figure 1. The laboratory-scale biofiltration system consisted of the biofilter (*3*) made of PCV pipe, 100 mm dia., divided into three sections (I, II and III), each of 0.4 m high. Each of the sections was filled with filtration material up to 0.33 m. So, the total height of the filter bed equals to 1.00 m. First, flue gas was pre-conditioned. Air from the room was pumped to a vertical damping column (*2*) made of PCV pipe, 1.00 m long and 100 mm dia., filled with wet activated carbon up to 0.90 m. The wet air was then passed through the bubbler (*1*) filled with ethylbenzene, and through the mixing chamber (*6*) entered the biofilter from its top end. Volume occupied by vapour of ethylbenzene was a negligible part of the whole stream of the gas mixture, therefore it was assumed that the changes of vapour concentration did not change the moisture contents in the gas stream. Gas stream velocity was monitored with the rotameter (*5*). An appropriate concentration of ethylbenzene in the gas mixture was provided by adjustment of the gas stream volume flowing through the bubbler.

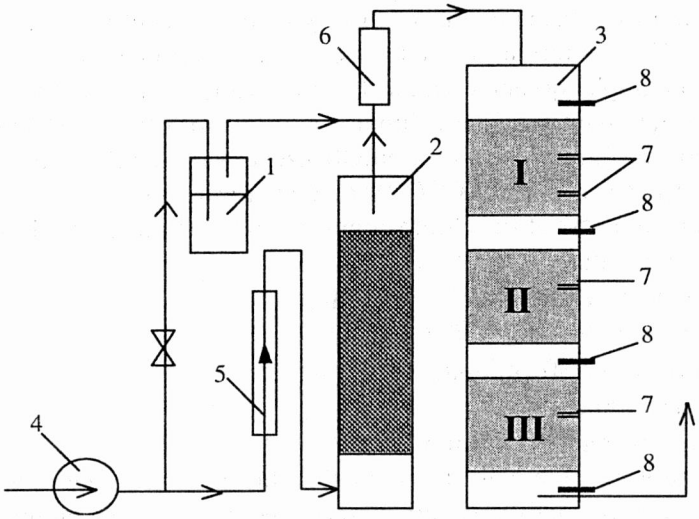

Fig. 1. The laboratory-scale biofiltration system used: *1* – bubbler for saturation of air with pollutant, *2* – air damping column, *3* – biofilter, *4* – pump, *5* – rotameter, *6* – mixing chamber, *7* – pipe connectors used for filter bed moisture control, *8* – pipe connectors for gas sampling

2.2. FILTRATION MATERIAL

Filtration material consisted of a mixture of garden peat (pH 3.5–4, manufactured by PRZEMTORF Ltd., Nowy Chwalim), activated sludge prepared in laboratory and molasse as a nutrient for bacteria. Average bacteria concentration in the bed approximated to $9 \cdot 10^6$ cfu/g.

Moisture content in the bed was measured using the EASY TEST microprocessor-controlled portable instrument that enabled determination of temperature and salinity of the filtration material as well. The test probe of the instrument was introduced into the biofilter bed through threaded pipe connectors (7).

2.3. OPERATION REGIME OF THE FILTER BED

Concentration of ethylbenzene in the flue gas stream was changed within the range from 17 mg/m^3 up to 1096 mg/m^3. Gas flow rate was maintained constant and equal to 0.25 m^3/h. Therefore, gas residence time in the filter was constant as well and amounted to 112 s. Moisture content in the bed varied within the range of 30–48% of the wet mass. Temperature of air varied from 20 to 25 °C.

2.4. METHOD OF THE CONCENTRATION DETERMINATION

Concentration of ethylbenzene in the air mixture passing through the biofilter was determined using the gas chromatography method. Samples of the gas mixture (each

of 1 cm^3 volume) were taken by means of a syringe, consecutively from the four pipe connectors (*8*). Concentration of ethylbenzene was determined using the GCHF 18.3 type gas gromatograph equipped with a flame-ionization detector (FID) and 1 m long column with 5 mm diameter. The column was filled with WAW 80/100 chromosorb and 10% carbowax. Concentration of ethylbenzene was calculated based on the specific peak area by means of the ACCORD computer program.

Operation parameters of the chromatograph can be itemized as follows:

- column temperature $T_K = 393$ K,
- sample injector temperature $T_D = 453$ K,
- detector temperature $T_{DT} = 473$ K,
- nitrogen flow rate 30 cm^3/min,
- air flow rate 300 cm^3/min,
- hydrogen flow rate 30 cm^3/min.

The concentration of ethylbenzene in the flue gas was determined every day. Moisture contents were analyzed every 10 days, increasing water supply, if required.

3. RESULTS AND DISCUSSION

Results of experiments are presented in the form of relations between the basic technological parameters of the process and the pollutant elimination capacity (EC). The relations are described by the following formulas:

$$\mathrm{IL} = \frac{Q_g C_{g,in}}{V} \ [\mathrm{mg/(m^3 \cdot s)}],$$

$$\mathrm{EC} = \frac{Q_g (C_{g,in} - C_{g,out})}{V} \ [\mathrm{mg/(m^3 \cdot s)}],$$

where:

IL – inlet load of the ethylbenzene [mg/(m^3·s)],

EC – ethylbenzene elimination capacity [mg/(m^3·s)],

Q_g – flow rate of gas volume [m^3/s],

$C_{g,in}$ – concentration of ethylbenzene at the inlet of the biofilter [mg/m^3],

$C_{g,out}$ – concentration of ethylbenzene at the outlet of the biofilter [mg/m^3],

V – volume of the filter bed [m^3].

Apart from determining the pollutant elimination capacity of the biofilter, the filter bed adaptation time and removal efficiency were measured. It was found that at a given concentration range the adaptation of the filter bed, which was equivalent to EC equal to 80%, took 17 days. Such relatively long adaptation period may be explained by the fact that from the very beginning the bed was loaded with considerable concentration of pollutant. Probably, this inhibited vital functions of the bacterial

flora [6]. Results of the experiments are shown in figure 2. Other experiments carried out by the authors proved that the adaptation period might be considerably shorter (4–8 days for ethylbenzene), provided that the process would be started with lower loads.

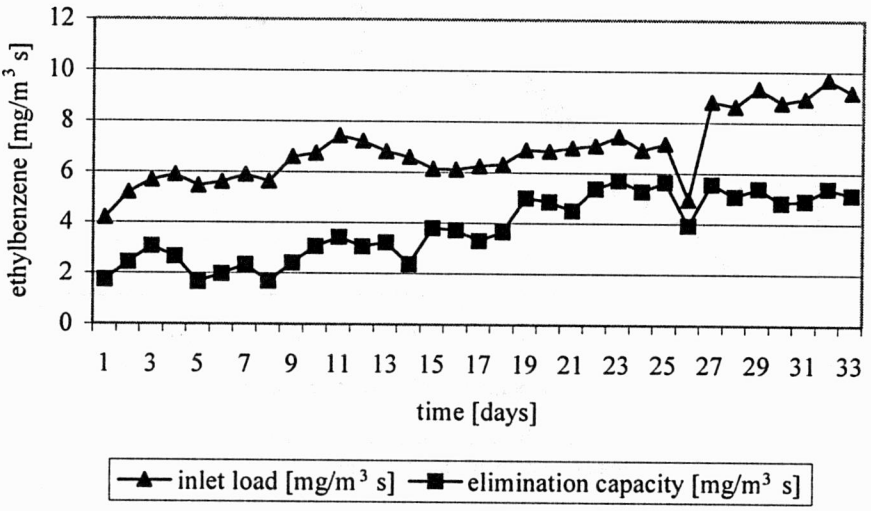

Fig. 2. Changes of the inlet concentration and of the ethylbenzene elimination capacity during the whole test series

The directly measured values were concentrations of ethylbenzene at the inlet and at the outlet of the biofilter. Relation representing the ethylbenzene removal efficiency versus the inlet concentration of the pollutant is shown in figure 3. All the results were registered for the steady state of the process.

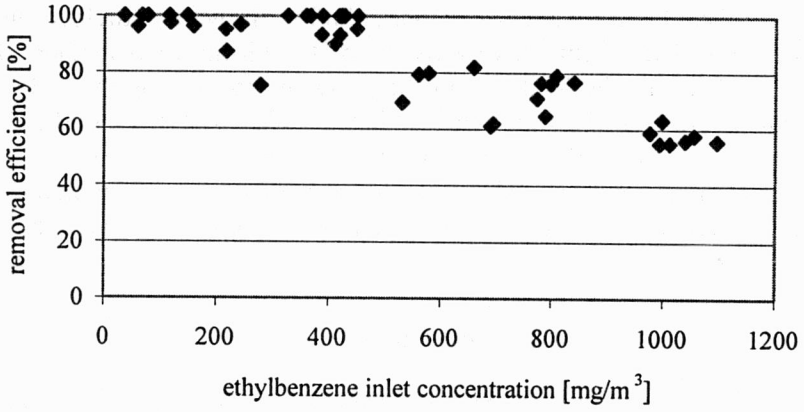

Fig. 3. Removal efficiency versus concentration of ethylbenzene at the inlet of the filter

As it can be seen in figure 4, the maximum load of ethylbenzene was 7 mg/(m^3·s). Further increase in the load does not increase the elimination capacity of the bed.

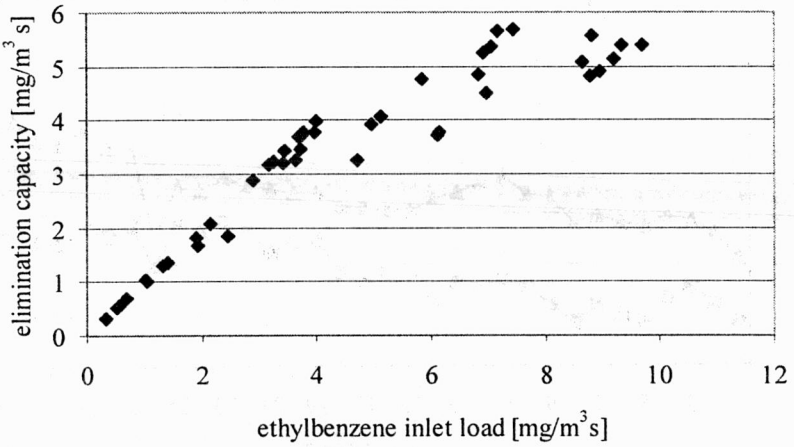

Fig. 4. Ethylbenzene elimination capacity versus load of ethylbenzene at the inlet of the filter

It was difficult to maintain constant water content in the filtration bed. Particularly upper parts of the bed got dry, which resulted in the reduction of the overall pollutant elimination capacity. Dampening the bed caused a rapid recovery of its former activity. The accelerated water loss may be explained by local heat generation due to intensive oxidation of organic pollutant by the bacterial flora [7].

4. CONCLUSIONS

It has been found that in spite of a poor solubility in water, ethylbenzene may be effectively removed from flue gas by means of the biofiltration method. The peat-based filtration bed may be loaded with the pollutant up to 7 mg/(m^{3}s). However, at the gas residence time of 112 s, further load increase does not increase the elimination capacity of the system over the maximum value of approx. 5.5 mg/(m^3·s).

Steady operation conditions of the biofiltration system were maintained without any problems, except that of the need for often dampening of the bed, particularly at higher ethylbenzene loads.

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BIOFILTRACJA POWIETRZA ZANIECZYSZCZONEGO ETYLOBENZENEM

Opisano wyniki laboratoryjnego badania biofiltracji powietrza zawierającego etylobenzen. Doświadczenia przeprowadzono w kolumnie wypełnionej modyfikowanym złożem torfowym. Wyniki pomiarów przedstawiono jako zależność szybkości i skuteczności biofiltracji od obciążenia początkowego złoża. Określono czas adaptacji mikroorganizmów, gdy znacząco zwiększono obciążenie złoża, oraz ich wrażliwość na zmiany wilgotności złoża.