INDUSTRIAL ECOLOGY

A BIOFILTER CONTAINING A BIOLOGICALLY
ACTIVE LAYER OF PINE BARK FOR REMOVING
VOLATILE HYDROCARBONS FROM AIR

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There are various industries (chemical, petroleum, wood-working, food, and so on) that discharge organic compounds (volatile hydrocarbons) into the atmosphere (butyl acetate, butanol, methanol, formaldehyde, phenol, benzene, toluene, xylene, and so on), which pollute the air. To clean the air, one needs efficient and cheap methods. These are met by biological methods based on biofilters in which the biologically active layer contains microorganisms that use the organic pollutants in their life activities as sources of water and carbon [1–8].

The filler in a biological air cleaner may employ natural material (straw, bark, peat, and so on) or synthetic material (crushed brick, glass tubes, and so on), which are usually produced in various processes. The choice is determined by the structure, porosity, sorptivity, working life, and cost. At Vilnius Technical University, we have made a biofilter containing a biologically active layer of pine bark, in which an association of natural microorganisms is cultured [9–12].

Here we evaluate the performance of the filter (over a period of 65 days) and determine the sorption behavior of various fractions (10–20 and 35–50 mm) in the biologically active layer made of pine bark. The filter received organic compounds (butyl acetate, butanol, and xylene) at concentrations up to 100 mg/m^3.

The filter (dimensions $0.5 \times 0.48 \times 2.0$ m) consisted of five active layers, which were separated by grids [2–5], which provided a uniform air distribution. The polluted air was passed through all five layers by means of a fan. The flow rates (56.70–144.69 m^3/h) and speeds (0.8–2.0 m/sec) were regulated with slides in the inlet and outlet pipes.

The air speeds in the inlet and outlet pipes were measured with a TESTO-452 instrument containing a thermocouple. The error of the instrument increases with the air speed up to 2 m/sec.

The aerodynamic resistance of the active layer was measured with a DSM-1 differential manometer. Each measurement was made five times.

The filler was first moistened, and then nutritive elements were added and the filter was biologically activated by passing organic substances through it.

In treating air, the filling should be kept at constant temperature (about 30°C), humidity (about 60%), and pH 7.2, which may be measured with a pH 538 meter. The water content was determined periodically by weighing. The samples of pine bark were dried to constant mass at 100–105°C.

The performance was determined with butyl acetate, butanol, and xylene at various concentrations, which were obtained by heating these compounds in a test tube on a controlled hotplate. The temperature of the air coming for cleaning was 20–55°C. We used six different concentrations of the volatile compounds with intervals of 15–20 mg/m^3 (up to 100 mg/m^3) to compare the oxidation capacity in the activated pine bark. Air samples were taken before entry to the filter and after it for 15 min at a speed of 0.2 liter/min by means of an Airchek 224-PCXR8 instrument, which employed glass collectors made in the USA (diameter 4.0 ± 0.1 mm, length 7.00 ± 0.01 m) filled with activated charcoal (0.30–0.85 mm). The concentrations were determined with a Hewlett Packard 5890 gas chromatograph, whose flame ionization detector had a sensitivity of
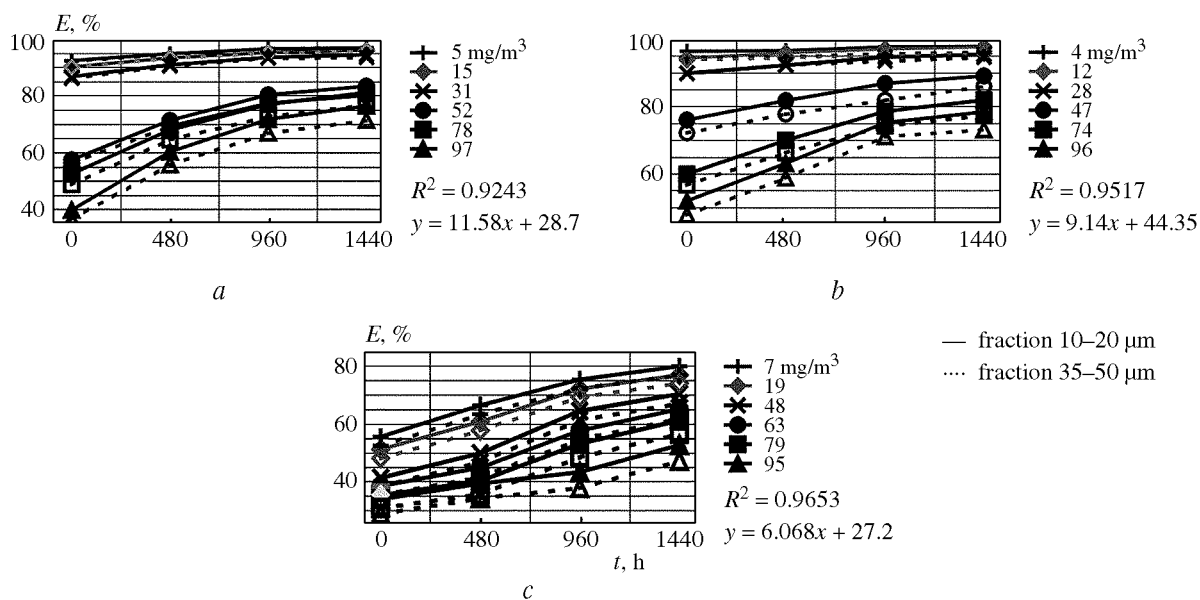

Fig. 1. Biofilter effectiveness E as a function of time t in removing butyl acetate (a), butanol (b), and xylene (c) from air.

$4 \cdot 10^{-9}$ mg/sec. The glass column (diameter 3.0 ± 0.1 mm, length 2.00 ± 0.01 m) was filled with chromosorb WHP (fraction 0.15–0.18 mm) and 10% OB-101. Column temperature 90°C, sensor 250°C, evaporator 200°C. Chromatography gave the concentrations, and the results were used to calculate the performance.

To determine the sorption parameters, we used six organic compounds at various concentrations differing by 15–20 mg/m^3 (up to 100 mg/m^3). Every 15 min, we took samples at intervals of 5 cm in depth in the horizontal and vertical directions and treated them with carbon disulfide (2 ml). Then the samples were analyzed with the Hewlett Packard 5890 chromatograph. An HP5 capillary column (diameter 0.53 ± 0.10 mm, length 30.00 ± 0.01 m) contained a liquid phase composed of 5% diphenyl and 95% dimethyl polysiloxane. Column temperature 40°C, detector and evaporator 250°C.

The experiments were conducted over 65 days with gradually increasing concentrations of the various compounds and changes in the filter working conditions in order to determine the performance and the sorption parameters of the pine bark in various fractions (10–20 and 35–50 mm).

We used butyl acetate, butanol, and xylene at various concentrations, which were passed through the layers at 2 m/sec at initial temperatures of 20–55°C, from which we established the response of the filter and the performance in sorption in the active layer (Figs. 1 and 2).

After 65 days of operation at low concentrations (less than 30 mg/m^3), the performance attained 80–98%. The performance fell as the concentrations of these compounds increased from 30 to 100 mg/m^3, so the higher concentrations had a depressive effect on the microorganisms: their reproduction was affected and their capacity to oxidize the organic compounds (Fig. 1) and so on. The same factors may explain the reduced performance in sorption (Fig. 2), so the filler volume should be increased if the pollutant concentrations are to increase.

The sorption performance of the active layer was higher for the butyl acetate and butanol, which are also readily oxidized, by comparison with xylene.

The performance is also affected by the fraction. The coarse fraction (35–50 mm) on replacement by the finer fraction (10–20 mm) showed an improvement in performance by 10–15%.

This occurs because the finer fraction has a larger surface and more microorganisms living in it. This regularity applied for all three organic compounds (butyl acetate, butanol, and xylene) at various concentrations.
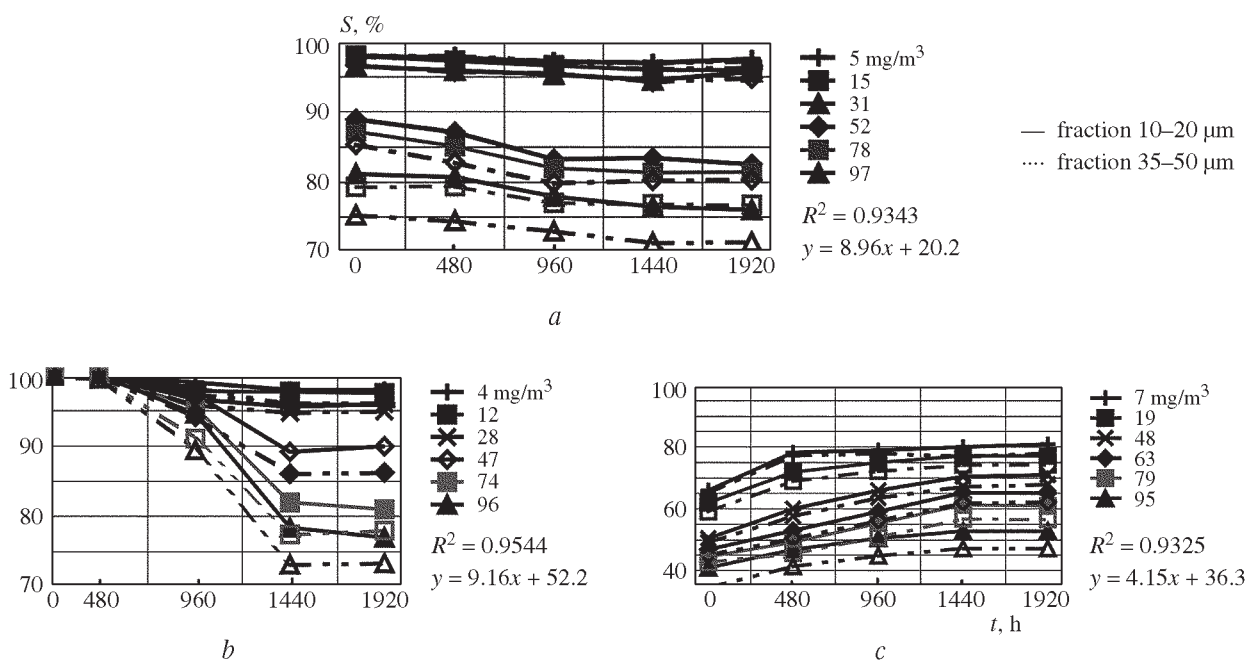
S, %

100 — 90 — 80 — 70

0   480   960   1440   1920

5 mg/m³
15
31
52
78
97

— fraction 10–20 μm
···· fraction 35–50 μm

$R^2 = 0.9343$
$y = 8.96x + 20.2$

a

100 — 90 — 80 — 70

0   480   960   1440   1920

4 mg/m³
12
28
47
74
96

$R^2 = 0.9544$
$y = 9.16x + 52.2$

b

100 — 80 — 60 — 40

0   480   960   1440   1920

t, h

7 mg/m³
19
48
63
79
95

$R^2 = 0.9325$
$y = 4.15x + 36.3$

c

Fig. 2. Sorption performance S of biologically active layer in relation to time t in removing butyl acetate (*a*), butanol (*b*), and xylene (*c*) from air.

The filter effectiveness and the sorption performance of the biologically active layer were examined every 20 days. In the initial stage (up to 20 days), the pine bark layer sorbed butyl acetate and butanol well (up to 75–100%) by comparison with xylene, which is sparingly soluble in water (up to 35–65%, Fig. 2*a–c*), while the numbers of microorganisms adapted to these pollutants were fairly low: up to $2 \cdot 10^6$ cfu/g (cfu is colony formation unit for the microorganisms).

At 20–40 days after the start, the layer became more active and the effectiveness rose, but the sorption performance fell somewhat (15%). At the same time, in parallel with the cleaning of the air, the sorption of the xylene by the biologically active layer occurred (Fig. 2*c*). The difference in sorption behavior is due to the weak activity of the biological medium.

At 65 days after the start, there was equilibrium between the sorption and the biochemical mechanisms, i.e., the volume of sorbed pollutant became equal to the volume of oxidized material (60–90%, see Fig. 1*a–c*, and Fig. 2*a–c*). These results were obtained with a rapid increase in the number of microorganisms to $(4.1–8.4) \cdot 10^6$ cfu/g.

These results show that the performance in removing volatile hydrocarbons from air is dependent on the activation time of the pine bark layer. For example, with an initial butyl acetate concentration of 78 mg/m³, the performance after 92 h was 57%, as against 62% after 480 h, 72% after 960 h, and 79% after 1440 h. This means that the active layer acquired more active associations of natural microorganisms. The longer the activation of the layer by organic pollutants, the better the performance in removing air and the better the layer sorption.

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