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INVESTIGATION OF CLEANING EFFICIENCY OF A BIOFILTER WITH AN AERATION CHAMBER

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Abstract. The investigation was carried out using a biological air-treatment device, i.e. a biofilter with an aeration chamber filled with water saturated with biogenic elements. To accelerate the absorption of organic compounds, air polluted with volatile organic compounds is directed to a water reservoir installed in the lower part of the filter where organic compounds are destructed. In the process of aeration, microorganisms propagate in the chamber, degrading part of pollutants to harmless products, carbon dioxide and water. Since all hydrocarbons are water-soluble, the aeration chamber is the first phase in a hydrocarbon degradation process. Application of such a polluted air-feeding model improves the sorption qualities of a charge. When relative air humidity reaches 100%, water-drops evenly distribute over the entire surface area of the charge and improve the activity of microorganisms. Having passed through the aeration chamber, polluted air is filtered via charges of a different origin, composed of zeolite, foam, wood chips or their mixtures. The carried out experiment shows that the best charge filtering capacity is achieved when supplying air polluted with acetone at the rate of 0.1 m/s. At the initial pollutant concentration of 115 mg/m^3 the biofilter treatment efficiency reached 96%. The aeration chamber installed in the biofilter increases both microbiological activity of the charge and air treatment efficiency.

Keywords: biofilter, sorbents, biodegradation, aeration, adsorption, absorption, volatile organic compounds.

1. Introduction

One of the main issues important to many countries of the world is rational use of natural resources and protection of the environment from different pollutants that are harmful not only to the environment but to human health as well (Baltrėnas *et al*. 2004).

Branches of industry, such as chemical, varnishes and paints production, oil refinement or food industries, use a lot of organic substances which in different ways access the atmosphere. The most widely spread organic compounds include acetone, butanol, toluene, xylene and others. Volatile organic compounds, evolved into the atmosphere as a result of human activities, contribute to the formation of photochemical oxidising agents a high concentration of which does harm to human health, flora and, in general, to the environment (Baltrėnas *et al*. 2004; Jeong *et al*. 2006; Laškova *et al*. 2007).

Presently, one of the most efficient air treatment methods is biological air treatment using certain cultures of microorganisms. The application of this method is promising when spontaneous cultures of microorganisms are cultivated in a charge. In this case biological air treatment is cheap, efficient and does not produce secondary pollutants (Baltrėnas *et al*. 2004).

Biological air-treatment devices are divided into three main groups: bioscrubbers, biotrickling filters and biofilters (Kennes and Thalasso 1998).

In bioscrubbers, polluted airflow is sprayed with an activated biomedium where organic pollutants are absorbed and degraded by microorganisms. Pollutants are most often degraded in bioscrubbers using an active sludge suspension. Devices of such a type are distinguished by aerodynamic resistance and high efficiency. High treatment efficiency (up to 99%) of a bioscrubber is achieved by degrading organic compounds having a high water-solubility rate such as ethyl acetate or butyl acetate. However, the device treatment efficiency falls to 50% when high concentrations of pollutants (1.000 mg/m^3) and poorly water-soluble organic compounds, such as toluene, are passed through it.

The basic element of biotrickling filters is a filtering medium composed of artificial charges such as polyurethane, linen textile, activated carbon, pearlite and scrap glass. The application of artificial charges in the process of biofiltration helps to extend the device service life, reduce aerodynamic resistance as well as the area of a sorbtion surface of the charge. Activity of the biomedium on the charge is maintained by spraying the charge with fine activated water drops. However, it is difficult to maintain microbiological water activity in biorickling filters of such a structure because spontaneous microorganisms do not develop on the surface of an artificial charge, and continuous introduction of individual microorganism cultures into the charge is expensive (Kennes and Thalasso 1998).

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Presently, the application of biofilters to remove volatile organic compounds from the air is growing. Biofilters, differently from biotrickling filters, can be charged only with charges composed of organic or organic and inorganic mixtures. The charge-humidifying control has to be ensured in the devices of such a type. The charge humidity of presently used biofilters is maintained by supplying the device with prehumidified air from a humidifying chamber installed before the filter or by spraying the charge with the help of sprayers installed over it (Kennes and Thalasso 1998).

Microorganisms need humidity to transport biogenic elements (K, N, P), enable metabolism processes and maintain a cell structure. Excess humidity is unacceptable because of the following:

1. when water occupies a large part of charge pores, air permeability and aeration efficiency decrease but the cleaning efficiency rises;
2. excessive humidity reinforces washing of pollutants and biogenic elements out of the charge.

In the process of treatment, the content of humidity changes. When passing through the charge, vapour-saturated air removes humidity thus reducing charge's humidity. But at the same time the process of biodegradation converts organic compounds into carbon dioxide and water and partially restores the content of humidity. 1.5 kg of water forms during decomposition of 1 kg of hydrocarbon. In the majority of cases, this water amount is insufficient, and the charge has to be additionally watered.

Microorganisms are capable of using all organic and inorganic carbon compounds for plastic metabolism. The most important in this group are bacteria and micromycetes. Bacteria account for their major part. They are capable of taking various hydrocarbons from the environment and are characteristic of a short life cycle. Most widely-spread, such as genuses *Arthrobacter, Acinetobacter, Pseudomonas, Bacillus, Flavobacterium, Mycobacterium, Micrococcus, Rhodococcus,* contain bacteria capable of oxidising hydrocarbons (Jankevičius and Liužinas 2003; Malhautier *et al*. 2005; Jeong *et al*. 2005; Laškova *et al*. 1997).

The efficiency of the biological air treatment process depends on the rate of microorganism culture growth in the biomedium. Having excess nutrition, microorganisms grow when the biofilter is continuously supplied with pollutants, and microorganisms are activated during initial air treatment (Liu *et al.* 2007).

One of essential conditions for microorganisms is a regular supply of oxygen which is used by microorganisms for pollutant oxidation and respiration. Therefore, in the process of air treatment, oxygen has to be supplied so that its amounts are sufficient to oxidise pollutants, and its concentration is not lower than minimal (0.25 mg/l).

Solution of oxygen in water is a diffusive process happening in a two-phase system: gaseous and fluid. Diffusive mass exchange takes place via the surface of a phase contact. Mass exchange velocity is described by the Fick's law:

$$\frac{dM}{dt} = -DA\frac{dC}{dy}, \tag{1}$$

where: $\frac{dM}{dt}$ – mass exchange velocity, mg/s; D – the diffusion coefficient, m^2/s; A – area via which gas diffuses into solution, m^2; $\frac{dC}{dy}$ – the concentration gradient, i.e. dependence of concentration change on range, $mg/m^3 \cdot m$.

The intensity of aromatic compound biodegradation depends on the number of the structure rings and the degree of condensation. The more condensed a multi-ring compound, the slower its mineralisation. It should be noted that the capacity of microorganisms to degrade aromatic compounds is nearly inversely proportional to the number of rings in their structure. Individual hydrocarbons of a condensed structure with four or more rings are degraded slowly (Lugauskas *et al.* 1997).

The key factor predetermining a microbe propagation rate and biochemical reaction intensity is temperature. Various groups of microorganisms have accommodated to living at different temperatures. Temperature for microorganisms, like for other organisms, may be minimal, optimal or maximal. Where temperature falls below the minimum or rises above the maximum, vital processes are disturbed. Optimal temperature is the best for microorganisms to propagate. For instance, the genera of psychrophilic and mesophilic microbes, such as *Pseudomonas* and *Achromobacter*, can propagate in the temperature range from 10 to 30 °C. In order to improve the treatment efficiency of a biofilter, the optimum temperature of the biomedium has to be maintained in the device.

Pseudomonas culture, actively participating in the destruction processes of organic compounds, is the most common in nature. The *pseudomonas fluorescens* bacteria are present in water and on the surface of plants. The bacteria *Pseudomonas fluorescens* of the *Pseudomonas* genus, evolved from the substrates of water and wood, accounted for 55 and 67%, respectively (Tekorienė and Lugauskas 2001).

The main element of a biological air-treatment device is a filtering medium that is necessary as a substrate of microorganisms and their provider with the required nutrients. In practice, charges of a natural origin are used as filtering media: compost, peat, wood chips, barks, active sludge (Zigmontienė and Baltrėnas 2004).

Charges of an artificial origin, composed of polyurethane, propylene, polyethylene, glass, ceramic balls and other materials, are also often used. However, affected by microorganisms, all these materials decompose after some time (Baltrėnas *et al*. 2004; Yun and Ohta 1998; Torkian *et al*. 2003).

With the aim of extending the life cycle of the charge and at the same time increasing the treatment efficiency of the device, several treatment techniques, biological and adsorptive ones, can be combined. As zeolite has a regular structure with pores of an equal size and is distinguished by a big internal area of the specific surface as well as thermal stability, it is widely applied in air treatment as an adsorbent. Upon mixing wood chips with zeolite, the life cycle of the charge is extended and the sorbtion properties of the filtering medium are improved

(Baltrėnas and Paliulis 2002). Spontaneous microorganism cultures will be able to develop not only in wood chips but also in zeolite of an inorganic origin (Luo and Lindsey 2006). Microorganisms that accumulate on a biofilm, forming on the zeolite surface, will decompose organic compounds in zeolite pores. To maintain better sorbtion properties of the charge, wood chips can be mixed with other charges having a bigger sorbtion surface, such as foam. In this case, the charge will be distinguished by better properties of humidity sorbtion, low density, low costs and a big area of the treated surface.

The investigation is aimed at determining the dependences of the biofilter treatment efficiency on the type and concentration of the pollutant supplied to the device as well as on filtration duration through the use of activated charges composed of natural zeolite, foam and wood chips, when supplying the biofilter with polluted air during the fluid phase.

2. Methods

Experimental tests were performed using a biological air-treatment device – a biofilter, supplied with air polluted with volatile organic compounds during the fluid phase (Fig. 1). To maintain a uniform distribution of an airflow and humidity within the charge layer and to reduce aerodynamic resistance of the charge, the filter contains 5 cassettes separated by metal meshes from each other. The experiments were carried out upon filling the cassettes with charges of a different origin (Fig. 2). First tests were performed by charging the cassettes with wood chips of 20–30 mm, afterwards wood chips were mixed with natural zeolite of a granule size of 10–15 mm, and later – with wood chips mixed with foam cubes of 30×30×20 mm in dimensions. A chip and granule mixture ratio by volume is 50:50%. Each layer of the charge is 0.85 m long, 0.65 m wide and 0.15 m high. After filling the cassettes, the charge is activated by maintaining 30±0.4 °C temperature, pH = 7±0.1 of the bio-medium acidity and the required content of biogenic elements in the biofilter. Stable temperature is maintained by a channel air heater installed in an air supply duct and connected to a temperature sensor and a sensor installed in the filter. With the aim of improving the adaptation of spontaneous microorganisms in the biofilm, the device is supplied with air polluted with volatile organic compounds. Thus, microorganisms receive the required oxygen and carbon.

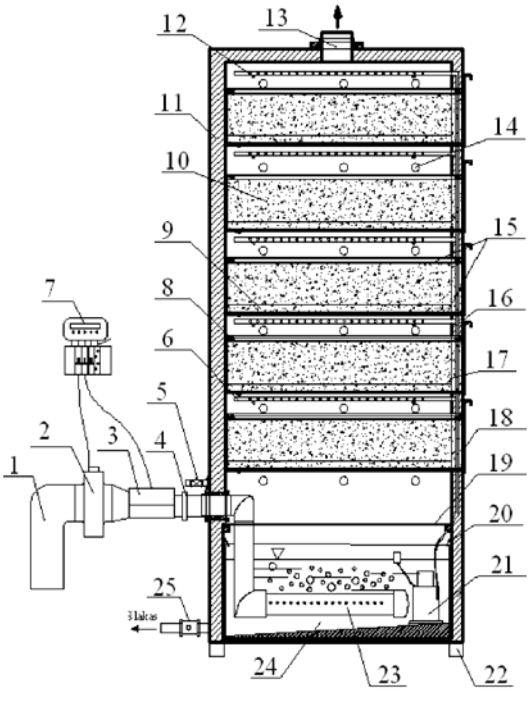

Fig. 1. Biofilter stand: 1 – polluted air supply duct; 2 – ventilator with turbine; 3 – channel air heater; 4 – airflow control valve; 5 – water supply branch with valve; 6 – charge humidifying system; 7 – control panel; 8 – frame for mesh fastening; 9 – angle bars; 10 – biofilter charge; 11 – biofilter wall; 12 – charge humidifying tube holders; 13 –treated air discharge duct; 14 – branches for air sampling; 15 – meshes; 16 – rubber hose; 17 – biofilter cassettes; 19 – protective mesh; 20 – water run-off tray; 21 – water pump; 22 – biofilter's leg; 23 – collector; 24 – aeration chamber; 25 – slag collection pipe with valve

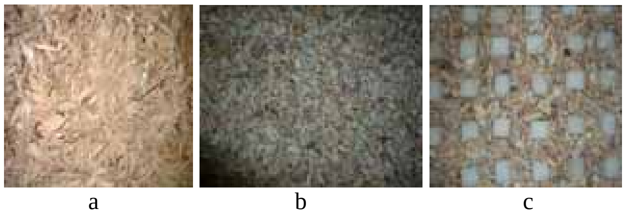

Fig. 2. Biofilter charges: a – wood chips; b – a mixture of natural zeolite and wood chips c – a mixture of foam cubes and wood chips

To accelerate the absorption of organic compounds, air polluted with volatile organic compounds is directed to the aeration chamber installed in the filter's lower part performing the function of an aeration tank (Fig. 3). In the process of aeration, microorganisms start propagating in the chamber and decompose part of pollutants.

Pollutants are volatilised to the filter by heating them on an electrical stove. The required initial concentrations of a pollutant are obtained by changing an organic compound heating temperature and a water dilution ratio.

Fig. 3. The biofilter is equipped with an aeration chamber

Upon setting the biofilter for operation, the charge is additionally humidified with water sprayers installed above each layer. Water saturated with biogenic elements is supplied to the sprayers with the help of a pump installed in a surplus water reservoir. Water pump operation is controlled by a time relay installed in the biofilter control panel, which actuates the water pump for 8 seconds per hour. During the experiment the pump operation time is set so that the biofilter maintains the charge humidity of 95%.

Around 7 l of water per day were sprayed over the charges to maintain the humidity of the total charge volume (0.387 m^3). The accumulated excessive waster runs off to the aeration chamber installed in the bottom part of the biofilter.

Humidity in the charge is controlled by a weighed method. Prior to sampling, weighing bottles with caps are dried for 1 hour at the temperature of 105 °C in a drying cabinet and afterward cooled in a desiccator. The dried weighing bottles with caps are weighed with an analytical balance.

Samples of 1–2 g each, taken with a pair of pincers are placed in the weighing bottles which are closed. A working sample is uniformly spread over the weighing bottle's bottom (0.2 g/cm^2). After being weighed, the weighing bottle with the sample is placed into the drying cabinet and dried for 3 h at a temperature of 105±2 °C. The dried sample is weighed and its humidity is determined (Baltrėnas and Zagorskis 2007).

To maintain the mechanical stability of the charge and ensure uniform distribution of humidity over the entire charge area, a sieve is installed above each layer with a mesh size of 3×3 mm.

To ensure microorganism growth and energy, a solution of mineral salts is necessary for the microorganisms to receive vital biogenic elements. The soil solution is composed of: K_2HPO_4 – 1 g, KCl – 0.5 g, $MgSO_4{\cdot}7H_2O$ – 0.5 g, $FeSO_4{\cdot}7H_2O$ – 0.1 g, $NaNO_3$ – 0,90 g, water – 1,000 g. This solution is poured into a water reservoir and sprayed over each layer of the charge. To ensure microorganism metabolism, the acidity pH = 7.0±0.1 is maintained in the biomedium. Buffer solutions composed of sodium and potassium hydrophosphates are used to ensure the acidity (Baltrėnas and Vaiškūnaitė 2003). The biomedium acidity is measured with a pH-metre.

To maintain the required temperature of the biomedium, an air supply duct is installed with a channel air heater that heats the air supplied to the biofilter up to a constant temperature of 30±0.4 °C.

Different concentrations of acetone are passed through the charge for the maintenance of microorganism energy. Microorganisms use acetone as food by evolving the products of metabolism, i.e. CO_2 and water, into the environment. Different concentrations are obtained by heating the pollutants on an electrical stove. The temperature of the vapour employed in the filter varies in the range of 20–50 °C. The initial acetone concentration reached 20 mg/m^3. The pollutant was supplied to the device 4 times a day for 15 minutes each time. Later, the concentration of the organic compound was increased by 20 mg/m^3 each time and the acetone supply duration was prolonged to 1 h. The charge was activated for 2 weeks. To ensure a uniform airflow and pollutant concentration distribution over the entire area of the charge, an airflow distribution collector is installed in the bottom part of the filter.

After the charge activation, the device is supplied with acetone-polluted air. The concentration of acetone before five layers of the charge reaches 115 mg/m^3. To determine the pollutant concentration, air sampling is performed when maintaining a stable rate of the supplied airflow of 0.1 m/s. Upon sampling completion, the supplied airflow rate is increased to 0.2 m/s with a controllable airflow valve installed in the filter.

To determine airflow rate and temperature, sampling branches with screw-caps are installed before and after each cassette in the biofilter.

The branches are fixed to one wall in an air duct of a rectangular form. When measurements are not taken, the branches are sealed.

The air duct cross-section of a rectangular form is conditionally divided into identical rectangles by lines parallel to its walls. The measuring points are arranged in the centre of each rectangle. The number of measuring points in a rectangular air duct cross-section of 0.55 m^2 has to reach 25 (Fig. 4).

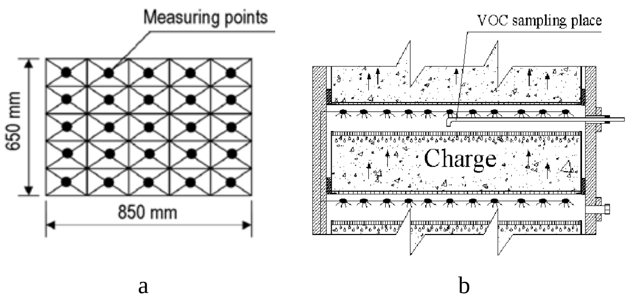

Fig. 4. Investigation places of the physical parameters of air and pollutants: a – airflow rate and temperature measuring places; b – volatile organic compound sampling place

The rate and temperature of the airflow passed through the charge are recorded with a Testo 400 meter.

To determine the dependence of biological air treatment device efficiency on the permissible concentration of pollutants, the concentration of supplied acetone was increased to 214 mg/m^3. The pollutant concentration was changed by heating it on an electrical stove. Afterwards the tests were repeated by increasing the initial acetone concentration to 311 mg/m^3.

Upon completion of experimental tests with acetone, unpolluted air was supplied to the device for 3 hours. This accelerated the desorbtion of acetone vapour. Afterwards tests were repeated with other pollutants, butanol and toluene.

Upon completing tests with wood chips, the biofilter is loaded with another charge composed of a mixture of wood chips and zeolite. After that the experimental tests were repeated using a mixture of wood chips and foam cube, and a combination of wood chips, zeolite granules and foam cubes.

To determine the dependence of charge treatment efficiency on a charge layer height, the concentrations of pollutants were measured before and after each cassette. To determine the concentrations, air samples were taken in special sampling places, and each measurement was repeated 3 times.

An air sample from the air duct was sucked through a stainless steel tube (d = 5 mm, l = 30 cm) into a clean gas pipette of 0.25 l at a rate of 0.25 l/min. The sucking lasted for 5 minutes. Upon sucking completion, the pipette's ends were via silicone hoses tightly stopped with glass plugs and the hoses were additionally tightened with Mohr's pinchcocks. The samples were analysed on the same day.

The concentration of pollutants was determined with a gas chromatographer SRI 8610 No. 942. The chromatographer sets the following parameters of the analysis process: nitrogenous gas velocity – 30 ml/min, hydrogen gas velocity – 30 ml/min, air rate – 200 ml/min, column thermostat temperature – 100±2 °C, vaporizer temperature – 200 ± 5 °C, detector temperature – 200±5 °C.

3. Investigation results

Upon completion of experimental tests with charges of a different origin and mixtures thereof it is determined that the highest treatment efficiency of the biofilter with an aeration chamber is achieved when using an activated charge composed of wood chips, zeolite granules and foam cubes. When using this charge, the biofilter efficiency reaches 95% (Fig. 5). Upon mixing wood with zeolite and foam granules, the adsorption and absorption properties of the charge are improved. Zeolite granules are distinguished by good porosity properties, whereas foam cubes – by the properties of humidity sorption. In the meantime, wood, as an organic sorbent, can be used by microorganisms to maintain their energy and vitality. Therefore, part of pollutants is adsorbed, part of them – absorbed in foam and biodegraded.

Acetone is most poorly degraded in a charge composed of wood chips and foam cubes. With this charge the filter's efficiency accounted for 84% whereas the device's aerodynamic resistance rose to 2,520 Pa. Such resistance was predetermined by water drops accumulated in foam pores. In addition, predominance of aerobic microorganisms, actively participating in the degradation of organic compounds, diminished in the charge.

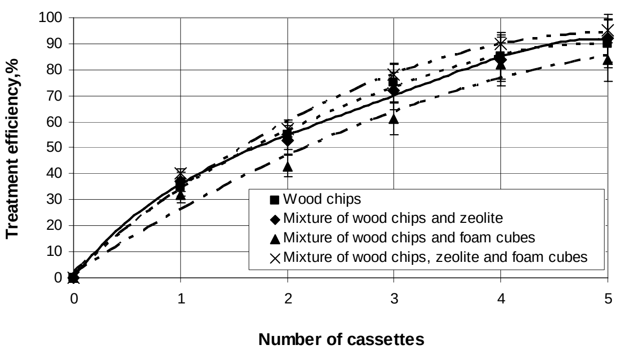

Fig. 5. Dependence of biofilter treatment efficiency on a charge type when the supplied airflow rate is 0.1 m/s, and the supplied pollutant – acetone

Dependence of biofilter treatment efficiency on the type of a pollutant supplied to the device upon loading the biofilter with a charge composed of a wood, zeolite granule and forma mixture, was obtained during the experiment. The data given in Fig. 6 show that microorganisms degraded acetone best. Upon degrading this pollutant, the filter efficiency reached 95%. Acetone mixes up with water well and is fully soluble in it, therefore acetone vapour is absorbed well in a biofilm that forms on the charge surface.

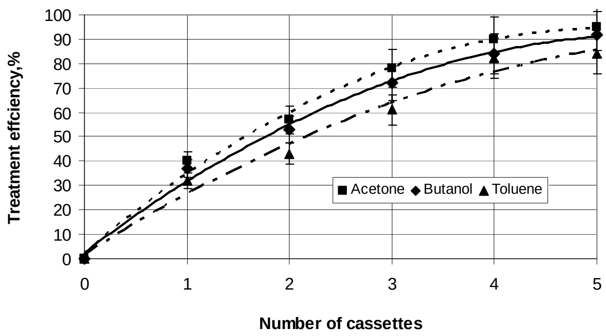

Fig. 6. Dependence of biofilter treatment efficiency on the number of cassettes when the supplied airflow rate is 0.1 m/s

The biofilter treated toluene-polluted air worst. Toluene is less soluble in water, its solubility reaches 0.53 g/l, therefore it is worse absorbed in a biofilm. The biggest decrease in pollutant concentration was recorded under the charge layer that is the first from the bottom as this layer is exposed to the biggest load. Having passed through five charge layers, the concentration of toluene fell from 118 to 17 mg/m^3.

Upon determining pollutant concentrations before and after each cassette, the treatment efficiency of the biofilter using charges of a different origin was obtained. The highest efficiency was achieved when treating acetone-polluted air (Fig. 6). A high efficiency of the device is attained when using three charges of a different origin. Zeolite used for the experiments has a porous structure and a big area of the treated surface, therefore part of the pollutant is adsorbed on the charge surface.

A high biofilter treatment efficiency of 92% was achieved during supply of butanol-polluted air to the device. It can be assumed that a higher efficiency of air cleaning from butanol was predetermined by a better water-solubility of the pollutant. The water-solubility of butanol determined by the investigation reaches 3–5 g/100 ml of water. In addition, it is experimentally determined that microorganisms better propagate in substrates with a bigger content of dissolved biogenic elements. The three last layers of the charge, composed of a wood, zeolite and foam mixture, rather evenly filtered pollutants of different types. A significant decrease in pollutant concentration was recorded in the first charge layer which is exposed to the biggest load of polluted air. After this layer, the concentration of acetone decreased from 115 to 69 mg/m^3. A decrease in pollutant concentration was predetermined by a high humidity of the charge (90%) and the amount of nutrients dissolved in water, which are assimilated by microorganisms in the process of metabolism.

Dependence of the biofilter treatment efficiency on different concentrations of a supplied pollutant was obtained during the experiments. The experiments were carried out when supplying air polluted with volatile organic compounds to the device at a rate of 0.1 m/s. When the concentration of substrate-acetone is high, the ferment is saturated, i.e. the substrate or the product molecules always take its active centre. Under such conditions, an increase in further substrate concentration has no effect on the reaction of fermentation velocity as all the active centres of the ferment are already occupied. Therefore, with increasing concentration of a pollutant, the device treatment efficiency decreases.

The best degradation of acetone is achieved when the initial pollutant concentration is lower. When the initial acetone concentration is 115 mg/m^3, the biofilter treatment efficiency reaches 95%. Upon raising the initial concentration up to 311 mg/m^3, the biofilter treatment efficiency fell to 80% (Fig. 7).

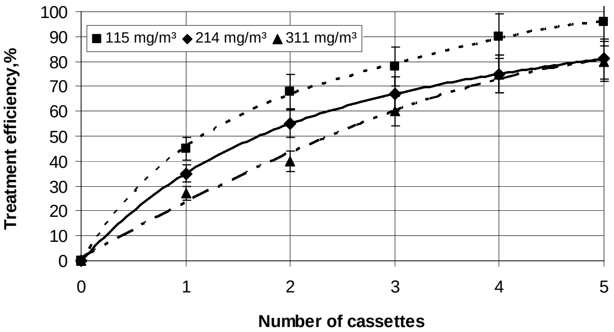

Fig. 7. Dependence of the biofilter treatment efficiency on the number of cassettes at different initial concentrations of acetone

With the aim of improving the biofilter treatment efficiency at high concentrations, it is necessary either to increase the number of cassettes in the device or reduce the rate of airflow supplied to the device. Thus, the time of biochemical reactions occurring in the filter will be extended.

When supplying butanol-polluted air to the device at the initial pollutant concentration of 116 mg/m^3, the device treatment efficiency after five layers of the charge reaches 92%, i.e. the pollutant concentration decreases from 116 to 10 mg/m^3. Upon increasing the supplied pollutant concentration up to 313 mg/m^3 the filter efficiency decreases to 78%, and the pollutant concentration – to 68 mg/m^3 (Fig. 8).

A lower efficiency of butanol cleaning from the air is predetermined by a lower water-solubility of this pollutant. The biggest decrease in butanol concentration was recorded after the biofilter's first cassette filled with an activated charge of natural zeolite, wood chips and form. After this charge layer the concentration of butanol at the initial concentration of 116 mg/m^3 fell to 38 mg/m^3. As butanol is less soluble in water, a big portion of the pollutant was adsorbed by zeolite which is distinguished by a porous structure and a large area of a sorbtion surface. Therefore, less water-soluble hydrocarbon is better sorbed by the charge composed of zeolite granules and wood chips. Butanol is locked in zeolite granules and stays longer in the activated charge. Thus, the duration of biochemical reactions is extended, which improves the synthesis of butanol and at the same time the device treatment efficiency.

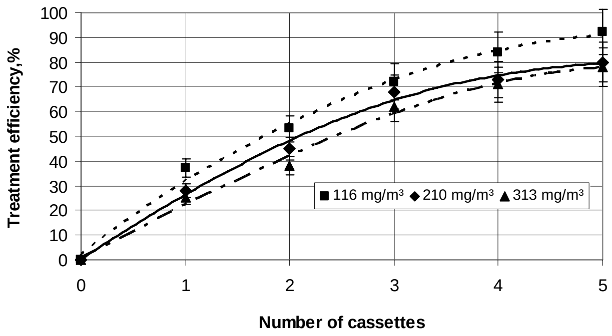

Fig. 8. Dependence of the biofilter treatment efficiency on the number of cassettes at different initial concentrations of butanol

The lowest treatment efficiency was achieved when treating toluene-polluted air. At an initial pollutant concentration of 118 mg/m^3, the biofilter treatment efficiency reached 84%. Upon increasing toluene concentration up to 314 mg/m^3, the efficiency decreases to 73% (Fig. 9).

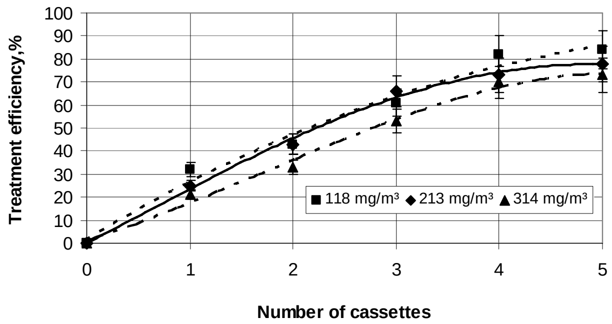

Fig. 9. Dependence of the biofilter treatment efficiency on the number of cassettes at different initial concentrations of toluene

Upon increasing the concentration of a pollutant supplied to the device, the biofilter treatment efficiency decreases as microorganisms do not manage to fully degrade volatile organic compounds. The best degradation of pollutants was achieved in the first layer of the charge. Considering the fact that butanol and toluene are less soluble organic compounds, their concentration after five charge layers was higher than that of acetone.

As the results given in Fig. 10 show, the biofilter treatment efficiency depends on the time of pollutant's contact with the charge. The longer duration of filtration, the higher treatment efficiency of the device. The time of polluted air filtration depends on the rate of airflow passed

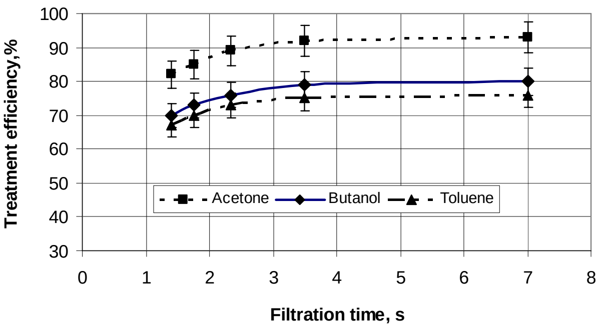

Fig. 10. Dependence of the biofilter treatment efficiency on filtration time at the supplied pollutant concentration of 115 ± 5 mg/m^3

through the filter. The best treatment efficiency of the device is achieved when polluted air is passed through the device at a rate of 0.1 m/s. At such an airflow rate, the time of pollutant filtration reaches 7 seconds during which acetone concentration decreases by 93%, butanol – by 80%, toluene – by 76% after biofiltering. The lowest treatment efficiency of 67% was recorded when tolune-polluted air was filtered through the charge, and the time of filtration was 1.4 s. The highest treatment efficiency of 82% was achieved when degrading acetone. Upon increasing the airflow rate up to 0.3 m/s at the pollutant filtration time of 2.3 s, the biofilter treatment efficiency in removing acetone increases up to 89%. It can be stated that upon increasing time of filtration the device treatment efficiency grows. Upon decreasing the rate of airflow passed through the device to 0.1 m/s, the cleaning efficiency of even such a poorly soluble and degradable pollutant, as tolune, also increases. Apart from that, toluene belongs to the group of aromatic hydrocarbons whose molecules form a six-membered ring. Hydrocarbon having more members in a benzene ring is more complicated, therefore, it is more difficult for microorganisms to degrade it.

4. Conclusions

1. By combining the biological and adsorption air treatment methods, a high biofilter treatment efficiency of 96% is achieved and the charge service life is extended.

2. The highest biofilter treatment efficiency of 96% is achieved when treating acetone-polluted air. A high degree of acetone removal is determined by good water-solubility of the pollutant.

3. When treating toluene-polluted air at the initial pollutant concentration of 118 mg/m^3, the device treatment efficiency reaches 84%. Lower treatment efficiency is predetermined by worse solubility of the pollutant in a biomedium.

4. With increasing concentration of the pollutant, the device treatment efficiency decreases. Upon increasing the concentration of acetone supplied to the biofilter from 115 to 311 mg/m^3, the treatment efficiency fell from 96 to 80%. Considering the fact that microorganisms do not manage to oxidise organic compounds, the filter is more efficient at lower concentrations of pollutants.

5. With increasing pollutant filtration time, the biofilter treatment efficiency also grows. The efficiency noticeably increases upon extending pollutant filtration time to 7.0 s when the biofilter treatment efficiency increases from 80 to 96%.

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VALYMO BIOFILTRU SU AERACINE KAMERA EFEKTYVUMO TYRIMAI

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S a n t r a u k a

Tyrimai atlikti naudojant biologinį oro valymo įrenginį – biofiltrą su aeracine kamera, pripildyta biogeninių elementų prisotinto vandens. Siekiant pagreitinti organinių junginių absorbciją lakiaisiais organiniais junginiais, užterštas oras nukreipiamas į filtro apatinėje dalyje įrengtą vandens talpyklą, kurioje vyksta organinių junginių destrukcija. Aeracijos proceso metu kameroje dauginasi mikroorganizmai. Jie suskaido dalį teršalų iki nekenksmingų produktų – anglies dvideginio ir vandens. Visi angliavandeniliai tirpūs vandenyje, todėl aeracinė kamera yra pirminis angliavandenilių skilimo proceso etapas. Taikant tokį užteršto oro tiekimo į įrenginį modelį pagerinamos įkrovos sorbcinės savybės. Santykinei oro drėgmei pakilus iki 100 %, vandens lašeliai tolygiai pasiskirsto per visą įkrovos paviršiaus plotą ir pagerina mikroorganizmų aktyvumą. Pratekėjęs aeracinę kamerą užterštas oras filtruojamas pro skirtingos kilmės įkrovas, sudarytas iš ceolito, porolono, medienos drožlių ir jų mišinių. Atlikus eksperimentinius tyrimus nustatyta, kad geriausiai įkrova filtravo 0,1 m/s greičiu į įrenginį tiekiamą acetonu užterštą orą. Esant pradinei šio teršalo koncentracijai 115 mg/m^3, valymo biofiltru efektyvumas siekė 96 %. Taigi biofiltre įrengta aeracinė kamera padidina įkrovos mikrobiologinį aktyvumą ir užteršto oro valymo efektyvumą.

Reikšminiai žodžiai: biofiltras, sorbentai, biodegradacija, aeracija, adsorbcija, absorbcija, lakieji organiniai junginiai.

ИССЛЕДОВАНИЕ ЭФФЕКТИВНОСТИ БИОФИЛЬТРА С АЭРАЦИОННОЙ КАМЕРОЙ

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Р е з ю м е

При выполнении экспериментальных исследований использовалось биологическое устройство для очистки воздуха – биофильтр с аэрационной камерой, заполненной водой и насыщаемой биогенными элементами. Для того, чтобы ускорить процессы абсорбции органических соединений, воздух, загрязненный летучими органическими соединениями, направлялся в резервуар с водой, установленный в низкой части фильтра, в котором органические соединения разрушались. В процессе аэрации в камере размножаются микроорганизмы, которые разрушают часть загрязнителей до безопасных продуктов: углекислого газа и воды. Так как все углеводороды растворимы в воде, в аэрационной камере происходит первоначальный процесс деградации углеводорода. При такой модели подачи загрязненного воздуха в устройство улучшаются сорбционные свойства загрузки. Когда относительная влажность воздуха достигает 100%, капли воды равномерно распределяются по всей площади поверхности загрузки и улучшают деятельность микроорганизмов. Пройдя через аэрационную камеру, загрязненный воздух фильтруется через загрузку различного происхождения, составленную из цеолита, поролона, щепы или их смесей. Эксперимент показал, что загрузка лучше всего фильтровала загрязненный ацетоном воздух, подаваемый в устройство со скоростью 0,1 м/сек. При начальной концентрации загрязнителя, равной 115 мг/м^3, эффективность биофильтра достигала 96%. Таким образом, установленная в биофильтре аэрационная камера увеличивает как микробиологическую активность загрузки, так и эффективность очищения воздуха.

Ключевые слова: биофильтр, сорбенты, биологический распад, аэрация, адсорбция, абсорбция, летучие органические составы.

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