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INVESTIGATION INTO THE AIR TREATMENT EFFICIENCY OF BIOFILTERS OF DIFFERENT STRUCTURES

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Abstract. Biological air treatment devices, biofilters, of four different structures with different origin charges, composed of natural zeolite granules, foam cubes and wood chips, were used for the experimental investigation. Biological and adsorptive air treatment methods are employed to clean the air from volatile organic compounds by mixing foam and zeolite with wood chips. The use of complex cleaning technologies improves the efficiency of the device and extends the useful life of a charge. The investigation showed that microorganisms predominant in the process of biocleaning could also propagate in the charges of inorganic origin composed of natural zeolite. The dependences of biofilter treatment efficiency on the nature, concentration and filtration time of the fed pollutant were determined when cultivating associations of spontaneous microorganisms in a charge. The best filtration efficiency of the charge was achieved when acetone-polluted air was fed into the device at a speed of 0.3 m/s. The treatment efficiency of a biofilter with a humidifying chamber reached 98% when cleaning the air from acetone with an initial concentration of the pollutant of 305 mg/m^3. The cleaning efficiency of the device increases when reducing the concentrations of pollutants fed into the device and increasing the time of their filtration.

Keywords: biofilter, volatile organic compounds, biodegradation, zeolite, adsorption, microorganisms.

1. Introduction

Branches of industry, such as chemical, varnishes and paints production, oil refinement or food, use a lot of organic substances, which in different ways access the atmosphere (Zarook *et al*. 1997; Laškova *et al*. 2007). Among the most widely spread organic compounds are acetone, butanol, toluene, xylene, and others. Volatile organic compounds emitted by mankind form photochemical oxidants, a big concentration of which makes harm to human health, vegetation and the environment in general (Jeong *et al*. 2006; Paulauskienė *et al*. 2009).

Various methods are used to clean the air from volatile organic compounds, including adsorption, absorption, condensation and oxidation. However, the application of these treatment techniques is expensive as charge regeneration and a sophisticated structure of devices are needed (Hashisho *et al.* 2007).

Presently, one of the most promising air treatment methods is biological air treatment using certain cultures of microorganisms. The application of this method is prospective when spontaneous cultures of microorganisms are cultivated in a charge. In this case biological air treatment is cheap, efficient and no secondary contaminants form in the process of biodegradation (Ardjmand *et al.* 2005; Baltrėnas and Zagorskis 2009).

The main element of biological air treatment devices is a charge, i.e. a filtering medium that may be composed of organic and inorganic substances. The charge is activated when it is being humidified with water saturated with biogenic elements. During the process of air treatment molecules of the supplied pollutant are slowly moving through the charge. After being transferred from the gaseous to the liquid phase they are degraded by microorganisms during fermentation processes occurring on the biofilm that has formed on the charge (Ardjmand *et al.* 2005; Engesser and Plaggemeier 2000).

The companies' purpose is to control better technological processes, maximum computerized and optimized device (Mačiulaitis and Malaiškienė 2009). Companies want to minimize the likely costs of the technology, but they also want to achieve the highest acceptable quality standards as well as to satisfy technological, architectural, and comfort requirements (Zavadskas *et al.* 2008).

Biological air treatment devices of different structures were widely investigated by the German scientists Hubner, Maier and Sabo (Chen *et al*. 2004).

In recent years trickling biofilters were started to be used for the reduction of volatile organic compound emissions into the ambient air (Lu *et al*. 2000; Cox and Deshusses 2002). In order to enlarge the surface area and extend the durability of the charge, trickling biofilters were charged with a synthetic charge of an inorganic origin, which is humidified with an activated solution saturated with nutrients (Liu *et al*. 2007).

To maintain the activity of microorganisms the charge is constantly humidified by spraying active water droplets over it. The active solution is supplied to the device by a circulatory pump. Volatile organic compounds are absorbed in the biofilm that has formed on the charge surface where microorganisms are degraded. Having passed through the charge the cleaned air is removed from the biofilter (Jantschak *et al.* 2004).

Microorganisms are capable of using all organic compounds for nutrient turnover. The most important in this group are bacteria and micromycetes. Bacteria account for the biggest share among them. They are capable of taking various hydrocarbons from the environment and are characteristic of a short life cycle. There are bacteria capable of oxidising hydrocarbons in the most widely spread genera of *Arthrobacter, Acinetobacter, Pseudimonas, Bacillus, Flavobacterium, Mycobacterium, Micrococcus* and *Rhodococcus*. Hydrocarbons are decomposed by microorganisms of more than 70 genera (Malhautier *et al.* 2005; Liu *et al.* 2007).

Biological air treatment efficiency in biofilters of different structures depends on the growth of microorganism cultures in the biomedium. As they have excessive food at the beginning of treatment they are growing when pollutants are regularly fed into the biofilter and microorganisms are activated.

The speed of the microorganism ferment reaction and the quantity of microorganisms depend on a substrate – the concentration and nature of hydrocarbon. In this case the substrate is a source of carbon and energy of microorganisms, whereas the intensity of aromatic compound biodegradation depends on the number of rings in a structure and the degree of condensation.

The most important factor predetermining the speed of microorganism propagation and the intensity of biochemical reactions in biofilters of different structures is temperature. To improve the treatment efficiency of a biofilter, the optimum, about 30 °C, temperature of a biomedium has to be maintained in the device. Therefore, when developing biofilters, major attention is devoted to biomedium heating systems or their elements.

A filtering medium, necessary as a substrate of microorganisms and at the same time supplying them with required nutrients is used in biofilters of different structures for biological air treatment. In practice the following charges of a natural origin are used as filtering media: compost, peat, wood chips, barks, activated sludge (Shareefdeen *et al.* 2003; Baltrėnas and Zagorskis 2009).

Charges of an artificial origin, composed of polyurethane, propylene, polyethylene, glass, ceramic balls and other materials, are also often used. However, all these materials are destructed by microorganisms in the course of time (Yun and Ohta 1998; Torkian *et al.* 2003).

The efficiency of biological air treatment largely depends on the humidification and heating systems installed in biofilters. The optimum charge humidity is 40–60%. Where humidity is insufficient, the charge starts cracking and becomes dried, which exacerbates air flowing and reduces the activity of microorganisms. This may result in the loss of the charge filtering properties. In order to avoid parching, the charge is humidified – water saturated with biogenic elements is sprayed over it. In the case of a high humidity of the charge anaerobic areas increasing its aerodynamic resistance emerge inside the filtering layer. This shortens the time of interaction of pollutants and microorganisms and at the same time reduces the treatment efficiency of the device (Baltrėnas and Zagorskis 2007).

In order to extend the useful life of the charge and at the same time increase the treatment efficiency of the device, several treatment methods, biological and adsorption, can be combined. As zeolite has a regular structure and pores of identical size and is distinguished by a large internal specific surface area as well as thermal stability, it is widely used in air treatment as an adsorbent. When wood chips are mixed with zeolite, the charge service life is extended and the sorption properties of the filtering medium are improved (Baltrėnas and Zagorskis 2009). The cultures of spontaneous microorganisms will be able to develop not only in wood chips but also in zeolite of an inorganic origin (Luo and Lindsey 2006). Microorganisms that have accumulated in the biofilm formed on the zeolite surface will degrade organic compounds accumulated in zeolite pores. To achieve better sorption properties of the charge, chips can be mixed with charges having a larger sorption surface, such as foam. In this case the charge will be distinguished by better properties of humidity sorption, a big area of the treated surface, low density and cost-effectiveness.

The aim of the investigation is, by using activated charges composed of natural zeolite granules, foam cubes and wood chips, to determine the dependences of the treatment efficiency of biofilters having different structures on the type and concentration as well as the filtration speed of the pollutant supplied to the device.

2. Methods

Experimental tests were performed using four biological air treatment devices of different structures, i.e. biofilters. The filters differ by the systems of air humidification and biomedium heating, air supply and discharge (Fig. 1). The main element of the filters is a filtering activated charge composed of zeolite granules, foam cubes and wood chips. In order to maintain a uniform distribution of the airflow and humidity within the charge layer and reduce the aerodynamic resistance of the charge, the filters were equipped with five cassettes separated by metal sieves from each other.

For the purpose of this investigation, each biofilter was charged with a different charge. The first biofilter was charged with wood chips of a fraction size of 20–30 mm, the second one – with a mixture of wood chips and natural zeolite granules of a fraction size of 10–15 mm. According to volume, the mixing ratio of granules and chips was 50:50%, a layer height – 100 mm. The third biofilter was charged with a mixture of wood chips and foam cubes of the dimensions of 30×30×20 mm. The chip and cube mixing ratio by volume is 50:50%, a layer height – 150 mm; and the fourth bio0filter was charged with a mixture of wood chips, zeolite granules and foam cubes. Material mixing ratio by volume is 33:33:34%. Each layer of the charge is 0.85 m long, 0.65 m wide and 0.15 m high (Fig. 2).

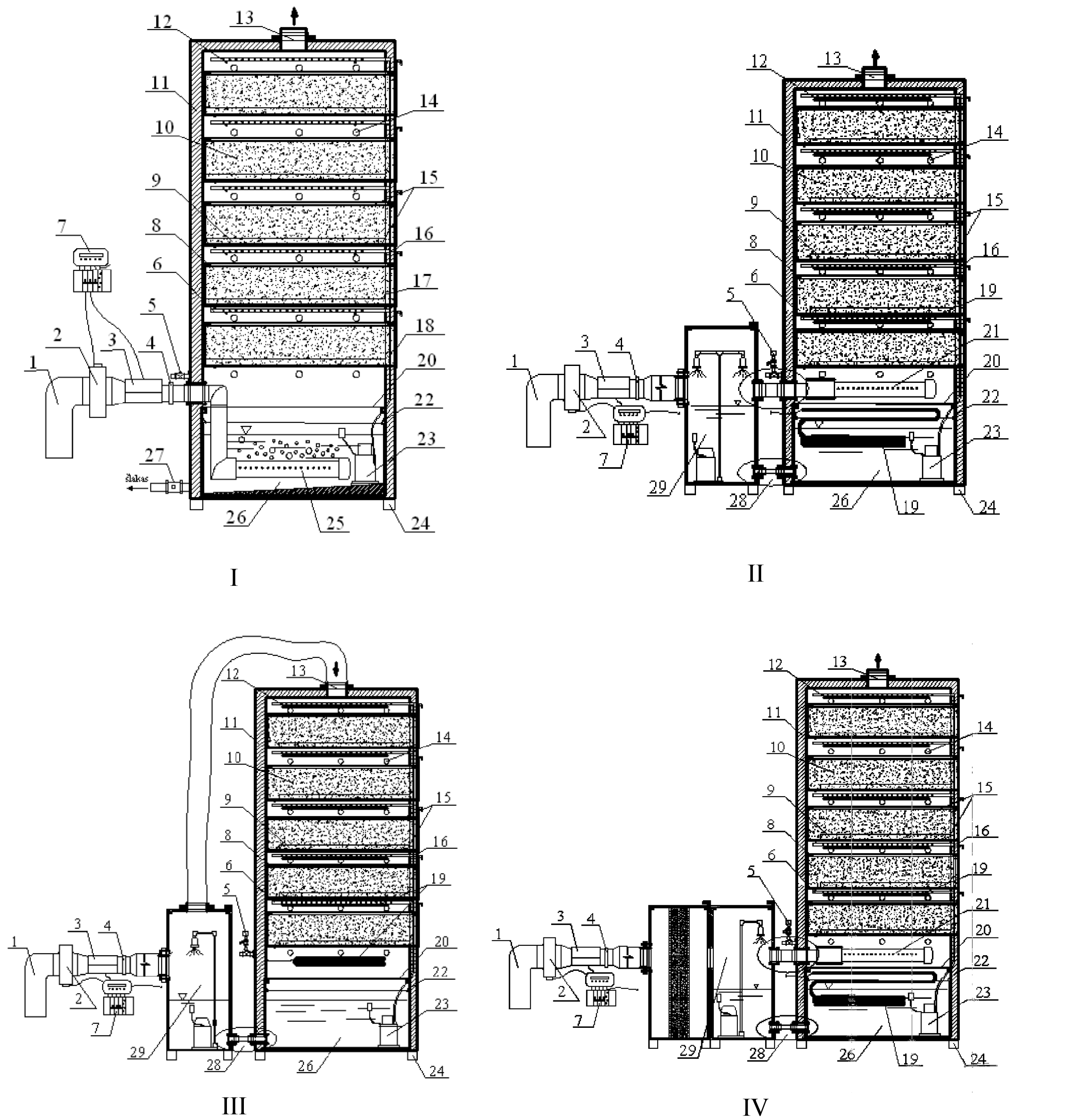


Fig. 1. Biofilter stands: I – biofilter prototype to which air is fed via the liquid phase; II – biofilter prototype with a humidifying chamber and air distribution collector; III – biofilter prototype with a humidifying chamber and airflow direction from the top to the bottom; IV – biofilter prototype with a three-step treatment system: 1 – contaminated air supply duct; 2 – ventilator; 3 – channel air heater; 4 – airflow control valve; 5– water supply nozzle with a valve; 6 – charge humidification system; 7 – control panel; 8 – frame for sieve fixing; 9 – angle bars; 10 – biofilter charge; 11 – biofilter wall; 12 – charge humidifying tube holders; 13 – treated air discharge duct; 14 – nozzles for air sucking; 15 – meshes; 16 – rubber hose; 17 – biofilter cassettes; 18 – cassette wall; 19 – heating cable; 20 – protective mesh; 21 – airflow distribution collector; 22 – water run-off tray; 23 – water pump; 24 – biofilter leg; 25 – collector; 26 – water reservoir; 27 – slag collection pipe with a valve; 28 – connection of humidifying chamber with biofilter; 29 – humidifying chamber; 30 – chamber filled with adsorbent

After filling up the cassettes, the charge is activated by maintaining the necessary temperature of 30 °C, the biomedium acidity of pH 7.0 and the quantity of biogenic elements in the biofilters.

With the aim of improving the adaptation of spontaneous microorganisms in the biofilm, the devices were supplied with the air polluted with volatile organic compounds. Thus, microorganisms receive the required oxygen and carbon.

Prior to setting the biofilters for operation, the charge was humidified using 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's control panel, which actuates the water pump for 8 seconds every hour. During the experiment the pump operation time is set so that the biofilter maintains the charge humidity of 75%.

The biofilters differ by air humidification systems. In the first biofilter (Fig. 1), having passed through the liquid phase the polluted air is humidified by 100%. The required air humidity, 95–100%, in the remaining biofilters is ensured by the installed humidification chambers.

To maintain the humidity of the entire charge volume (0.387 m^3), around 7 *l* of water are necessary in a day.

a b c

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

To maintain a uniform airflow and make excess water run off to the excess water reservoir installed in the bottom part of the filter, biomedium layers are separated by metal sieves. Humidity in the charge is controlled by the weighed method. Prior to sampling, weighing bottles with caps are dried for 1 hour at a temperature of 105 °C in the 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 into the weighing bottles, which are closed with caps. A working sample is uniformly spread over the weighing bottle's bottom (0.2 g/cm^2). After being weighed, the weighing bottle containing 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 measured (Baltrėnas and Zagorskis 2007).

To maintain 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 salt 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 – 1000 g. This solution is poured into the 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. The biomedium acidity is measured with a pH-metre (Baltrėnas and Vaiškūnaitė 2003).

To maintain the required temperature of the biomedium in all the biofilters, 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 °C. In the second, third and fourth biofilters each layer of the charge is heated individually. To avoid big temperature variation during charge humidification, an active water heating system is additionally installed in the second and fourth biofilters.

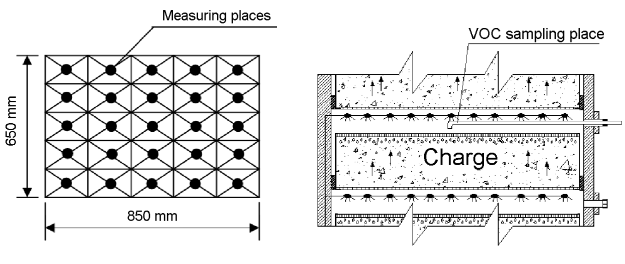
Different concentrations of acetone are passed through the charge for the maintenance of microorganism energy. Microorganisms use acetone as a source of energy by evolving the products of metabolism, i.e. CO_2 and water, into the environment. Different concentrations are obtained by heating the pollutants on an electrical stove. Temperature of the fed vapour varies in the range of 20–50 °C. The initial concentration of the supplied acetone 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 every two days and an acetone supply duration was prolonged to 1 h. The charge was being 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 the air polluted with acetone vapour. The concentration of acetone before five layers of the charge reaches 305 mg/m^3. To determine the pollutant concentration, air sampling is done when maintaining a stable rate of the supplied airflow of 0.3 m/s. Upon sampling completion, the supplied airflow rate is increased to 0.5 m/s with a controllable airflow valve installed in each biofilter. Experiments were repeated by increasing the supplied airflow rate to 0.7 m/s.

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

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

The air duct cross-section of a rectangular form is conditionally divided into identical rectangles by the lines in parallel to its walls. The measurement points are arranged in the centre of each rectangle. The number of measurement points in a rectangular air duct cross-section of 0.55 m^2 has to reach 25 (Fig. 3a).



a b

Fig. 3. Investigation places of the physical parameters of air and pollutants: a – airflow rate and temperature measuring places; b – volatile organic compounds sampling place

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

To determine the dependence of biological air treatment device efficiency on the initial concentration of pollutants, the concentration of supplied acetone vapour was increased to 515 mg/m^3. The pollutant concentration was changed by heating it on an electrical stove. Afterwards tests were repeated by increasing the initial acetone concentration to 712 mg/m^3.

Upon completion of experimental tests with acetone, unpolluted air was supplied to the device for 3 hours. This accelerates the de-sorbtion of acetone vapour. Afterwards tests are repeated with other pollutants, i.e. butanol and toluene. These pollutants were chosen because of their wide application in industries. In addition, these pollutants belong to different groups of organic compounds.

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 was done 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 the experimental tests, the dependences of biofilter treatment efficiency on the type of the biofilter charge and structure of the device were obtained. As the data presented in Fig. 4 show, the biofilter with the humidifying chamber degraded acetone best. Acetone was used for testing as a source of carbon. Acetone mixes well with water and is completely soluble in it and therefore acetone vapour better absorb on the biofilm that forms on a charge surface.

The charge composed of wood chips and zeolite granules was distinguished by the best sorption properties. A high treatment efficiency of the device, 98%, was achieved when using this charge. After measuring pollutant concentrations before and after each cassette, the results of the treatment efficiency of biofilters charged with charges of a different origin were obtained. The highest air treatment efficiency was reached when using a charge composed of wood chips, zeolite granules and foam cubes. The device treatment efficiency of 98% was obtained when using a mixture of the aforementioned materials. As zeolite has a porous structure and a big area of the treated surface, a part of the pollutant adsorbs on the charge surface. After the first layer the filter treatment efficiency reaches 45%, whereas after all the filtering layers – 98%. After inserting foam cubes into the charge, degrading of organic compounds is accelerated because of increased humidity of the biocharge.

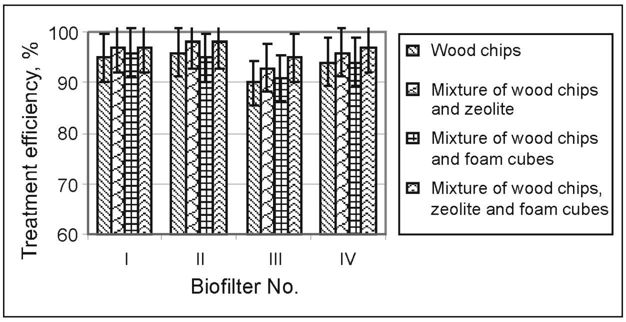


Fig. 4. Dependence of the treatment efficiency of biofilters of different structures on a charge type

The lowest treatment efficiency of 90% was obtained when using a biological treatment device with an airflow flowing from the top to the bottom (Fig. 1). Wood chips had the worst treatment properties in this filter. A high treatment efficiency of 97% was obtained in a three treatment step biofilter. Here, the polluted air was first treated in sorption cassettes filled with zeolite. A part of acetone vapour was absorbed in the humidifying chamber. It can be assumed that better air cleaning from acetone was predetermined by better solubility in water of the pollutant. In addition, it was determined experimentally that microorganisms propagated best in the substrates with the biggest content of dissolved biogenic elements. Depurated and humidified to 95±5%, the airflow was passed through the charge and afterward the pollutant concentration fell to 18 mg/m^3. A significant decrease in pollutant concentration was recorded in all the biofilters whose cassettes were filled with an activated charge composed of a wood chip, zeolite granule and foam mixture. After these layers the concentration of acetone vapour decreases to 98%. A decrease in pollutant concentration was influenced by the charge's high humidity that reached 95% and the amount of nutrients dissolved in water, which are assimilated by microorganisms during nutrient turnover – metabolism.

The dependencies of biofilter treatment efficiency on different concentrations of the supplied pollutant were obtained during tests. These tests were conducted by supplying the air polluted with volatile organic compounds to the device at a rate of 0.3 m/s. First, the device was supplied with the air polluted with acetone vapour. In the case of a big concentration of the substrate, acetone vapour, the ferment was saturated, i.e. the substrate or product molecules always take its active centre. Under such conditions a further increase in the substrate concentration has no influence on the speed of the fermentation reaction as all the ferment's active centres are already occupied. Consequently, with increase of pollutant concentration the device treatment efficiency decreases (Fig. 5).

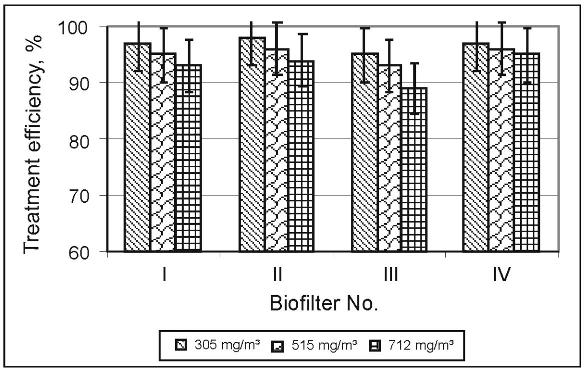


Fig. 5. Dependence of biofilter treatment efficiency on the concentration of acetone vapour supplied to the device

Acetone vapour is best degraded when the initial pollutant concentration is lower. When the initial acetone vapour concentration is 305 mg/m^3, the biofilter treatment efficiency reaches 98%. Upon increasing the initial pollutant concentration to 712 mg/m^3 the treatment efficiency of biofilters falls to 88%.

Thus, with increasing concentration of the pollutant supplied to the device the treatment efficiency of the biofilter is decreasing. When the air polluted with acetone vapour with a concentration of 305 mg/m^3 is supplied to the biological air treatment device, the treatment efficiency of the device reaches 98%. Upon increasing pollutant vapour concentration to 712 mg/m^3 the treatment efficiency of the biofilter with the humidifying chamber falls to 79%. The lowest device treatment efficiency of 89% was obtained when treating air polluted with toluene vapours. Upon increasing the initial pollutant concentration to 712 mg/m^3 the filter treatment efficiency falls to 89%. Thus, in order to increase the device treatment efficiency, the vapour concentration of the pollutant supplied to the device must be reduced. In addition, charges with good sorption properties must be used in the biofilter. The tests have shown that upon combining the biological and adsorption treatment methods, a high device treatment efficiency is achieved. When using natural zeolite the charge service life is extended, and upon mixing it with wood chips a high microbiological activity of the charge is achieved.

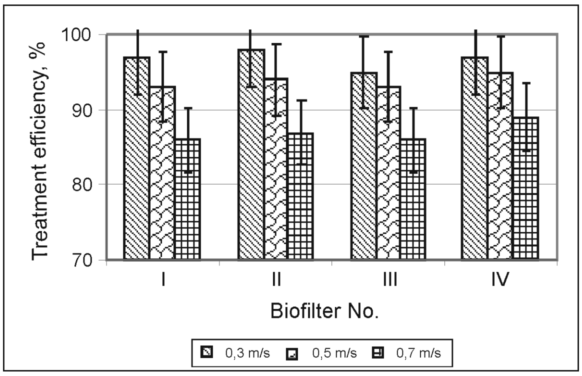


Fig. 6. Dependence of biofilter treatment efficiency on the rate of airflow passed through the device

In order to increase the treatment efficiency of the biofilter at high concentrations of pollutants either the number of cassettes in devices has to be increased or the rate of the airflow supplied to the device has to be reduced. This will prolong the time of biochemical reactions in the filter.

As the results given in Fig. 6 show, the biofilter treatment efficiency depends on the time of pollutant contact with the charge. The longer the duration of filtration of the polluted air, the higher the treatment efficiency of the device. The time of polluted air filtration depends on the rate of the airflow passed through the filter. The best treatment efficiency of the device is achieved when polluted air is passed through the device at a rate of 0.3 m/s. At such an airflow rate, the time of pollutant filtration reaches 7 s during which acetone vapour concentration after the biofilter decreases to 98 mg/m^3. The lowest device treatment efficiency of 85% was recorded when the air polluted with acetone vapour was filtered via the charge at a rate of 0.7 m/s. Upon decreasing the rate of the airflow passed through the charge to 0.5 m/s, the biofilter cleaning efficiency in removing acetone vapour rises to 93%. It can be stated that upon increasing the time of filtration the device treatment efficiency grows. Upon decreasing the rate of airflow passed through the device to 0.3 m/s, the cleaning efficiency of even such a poorly soluble and degradable pollutant as toluene also increases. Apart from that, toluene belongs to the group of aromatic hydrocarbons whose molecules are a six-membered benzene ring. Hydrocarbon having more members in a benzene ring is more complicated and therefore it is more difficult for microorganisms to degrade it. Dependence of biofilter treatment efficiency on the nature of the pollutants filtered through the charge is given in Fig. 7.

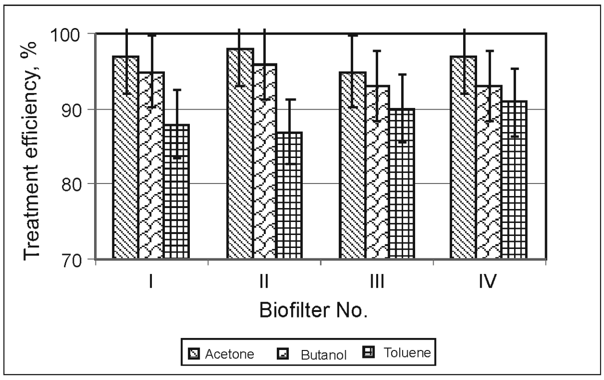


Fig. 7. Dependence of biofilter treatment efficiency on the nature of pollutants filtered through the charge

When butanol-polluted air was supplied to the device at the initial pollutant concentration of 305 mg/m^3, the device treatment efficiency after 5 layers of the charge reached 98%. The pollutant concentration decreases from 305 to 23 mg/m^3. Upon increasing the supplied pollutant concentration to 712 mg/m^3 the filter efficiency decreases to 89%, and the pollutant concentration falls to 39 mg/m^3 (Fig. 5). It should be noted that a major part of the pollutant was adsorbed by zeolite, which is distinguished by a porous structure and a big surface area of sorption. Thus, a hydrocarbon that is less soluble in water is better sorbed by the charge composed of zeolite granules and wood chips. Acetone is locked in zeolite granules and therefore stays longer in the activated charge. Thus, the duration of biochemical reactions is extended, which improves the synthesis of acetone and at the same time the device treatment efficiency.

The lowest treatment efficiency was achieved when treating toluene-polluted air. At the initial pollutant concentration of 305 mg/m^3, the device treatment efficiency reached 87%.

Upon increasing the concentration of pollutant supplied to the device, the biofilter treatment efficiency decreases as microorganisms do not manage to fully degrade volatile organic compounds. As the results given in Fig. 8 show, the biggest load falls onto the first layer of the charge that is composed of an activated charge of wood chips, zeolite granules and foam cubes. The poorest treatment properties were characteristic of the biofilter where the airflow flows from the top to the bottom. Better sorption properties were achieved in the biofilter with the humidifying chamber and airflow distribution collector. The biggest amounts of pollutants are degraded in the charge's first layer with 40% of the supplied pollutant being degraded.

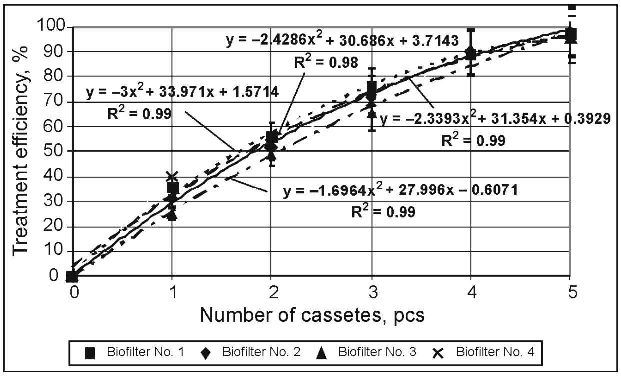


Fig. 8. Dependence of biofilter treatment efficiency on the number of cassettes in the device when the supplied pollutant concentration is 305±5 mg/m^3

Biofilters of different structures are characteristic of similar trends of acetone vapour concentration decreasing as all the devices are installed with humidification chambers and biofilter No 4 is installed with three treatment steps (Fig. 1). Therefore, a part of acetone vapour is absorbed in the first layers. The highest air treatment efficiency was recorded when using a biofilter with a humidification chamber and airflow distribution collector. The device air treatment efficiency reached 98%.

4. Conclusions

1. The highest air treatment efficiency was reached when using a charge composed of wood chips, zeolite granules and foam cubes. The use of a combination of these materials produces the device treatment efficiency of 98%. A high degree of acetone removal is predetermined by good sorption properties of the charge.

2. Acetone is best degraded when the initial pollutant concentration is lower. When the initial acetone vapour concentration is 305 mg/m^3, the biofilter treatment efficiency reaches 98%. Upon increasing the initial pollutant concentration to 712 mg/m^3, the treatment efficiency of biofilters falls to 88%. Poorer treatment efficiency is predetermined by worse solubility of the pollutant in the biomedium.

3. The biofilter with the humidifying chamber and airflow distribution collector sorbed pollutants best. The biofilter's cassettes were filled with a mixture of wood chips, zeolite granules and foam cubes. When using this charge the device treatment efficiency reaches 98%. This charge is distinguished by good biological and sorption properties.

4. Upon reducing the rate of the airflow passed through the charge to 0.5 m/s the biofilter treatment efficiency in removing acetone vapour rises to 93%. It can be stated that upon increasing the duration of filtration the device treatment efficiency grows. Upon decreasing the rate of airflow passed through the device to 0.3 m/s, the cleaning efficiency of toluene, a poorly soluble and degradable pollutant, also increases.

5. The biggest load falls onto the first layer of the charge that consists of an activated charge composed of wood chips, zeolite granules and foam cubes. As the tests show, the biofilters installed with a system of several treatment steps are distinguished by better treatment properties.

Acknowledgements

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ORO VALYMO EFEKTYVUMO SKIRTINGŲ KONSTRUKCIJŲ BIOFILTRAIS TYRIMAI

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S a n t r a u k a

Eksperimentiniams tyrimams atlikti naudota keturi skirtingų konstrukcijų biologiniai oro valymo įrenginiai – biofiltrai su skirtingos kilmės įkrovomis, sudarytomis iš gamtinės kilmės ceolito granulių, porolono kubelių bei medienos skiedrų. Poroloną ir ceolitą maišant su medienos skiedromis, lakiesiems organiniams junginiams iš oro valyti taikomi biologinis ir adsorbcinis oro valymo metodai. Įrenginio valymo efektyvumas pagerinamas bei įkrovos naudojimo trukmė ilgėja naudojant kompleksines valymo technologijas. Ištyrus nustatyta, kad biologinio valymo procese vyraujantys mikroorganizmai gali daugintis ir neorganinės kilmės įkrovose, sudarytose iš gamtinio ceolito. Įkrovoje kultivuojant savaiminių mikroorganizmų asociacijas nustatytos biofiltrų valymo efektyvumo priklausomybės nuo į įrenginį tiekiamo teršalo prigimties, koncentracijos, filtracijos laiko. Geriausiai įkrova filtravo 0,3 m/s greičiu į biofiltrą tiekiamą acetono garais užterštą orą. Šalinant iš oro acetoną, kai pradinė teršalo koncentracija 305 mg/m^3, biofiltro su drėkinimo kamera valymo efektyvumas siekė 98 %. Mažinant į biofiltrus tiekiamų teršalų koncentracijas bei didinant jų filtracijos laiką įrenginių valymo efektyvumas didėja.

Reikšminiai žodžiai: biofiltras, lakieji organiniai junginiai, biodegradacija, ceolitas, adsorbcija, mikroorganizmai.

ИССЛЕДОВАНИЯ ЭФФЕКТИВНОСТИ ОЧИСТКИ ВОЗДУХА БИОФИЛЬТРАМИ РАЗНЫХ КОНСТРУКЦИЙ

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Резюме

Для экспериментальных исследований использовались четыре устройства для биологической очистки воздуха – биофильтры разных конструкций. Загрузку биофильтров составляли гранулы естественного цеолита, поролон и древесина, которые использовались для очистки воздуха от летучих органических веществ.
В случае применения для очистки воздуха поролона и цеолита в смеси с древесиной применялся биологический и адсорбционный методы. Применение комплексных технологий способствует улучшению эффективности очистки воздуха и продлению срока применения загрузки. Исследования показали, что в процессе биоочистки микроорганизмы могут размножаться и в неорганической загрузке, состоящей из природного цеолита. Культивируя в загрузке ассоциации микроорганизмов, найдены зависимости эффективности биофильтра от характера загрязнителя, его концентрации, времени фильтрации. Лучше всего загрузка фильтровала воздух, загрязненный парами ацетона и подаваемый в установку со скоростью 0,3 м/с. Эффективность очистки воздуха от ацетона при начальной концентрации загрязняющих веществ в 305 мг/м^3 для биофильтра с камерой увлажнения составляла 98%. При снижении концентрации загрязняющих веществ, подаваемых в биофильтр, и повышении времени фильтрации загрязненного воздуха эффективность установки увеличивается.

Ключевые слова: биофильтр, летучие органические вещества, биологический распад, цеолит, адсорбция, микроорганизмы.

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