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Research into biological air treatment

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Biological air treatment method is based on the biological destruction using certain cultures of microorganisms. The method is simple and can be applied in many branches of industry.

The activated charge consisting of fir bark and wood in chips was used in this research. According to the research findings, the biggest reduction of pollutant concentration was recorded in the biofilter layers consisting of the fir bark charge. Having passed through two charge layers of 0.30 m thickness, the concentration of acetone decreased by around 50%. When using wood in chips the efficiency of acetone decreases. Such a reduction of pollutants is predetermined by a more porous layer of the charge the porosity of which reaches 60%. A bigger porosity predetermines better moistening of the charge as well as the emergence of more favourable conditions for the development of microorganisms. The charge is distinguished by the best cleaning properties when the airflow is supplied to the device at a small velocity, 0.2 m/s, because when the velocity is low the time of contact of the polluted air and the biocharge is extended. Seeking to extend the durability of the charge, it is recommended to clean the air using the mixture of fir barks and wood in chips. The research has proved that using the mixture of fir bark and wood in chips for the biological air treatment, the charge cleaning efficiency increases significantly and at the same time the durability of the biocharge is extended.

Key words: biofilter, biodestruction, acetone, microorganisms

INTRODUCTION

The issue of emissions of atmospheric pollutants has been one of the most urgent environmental problems worldwide. The branches of industry such as organic chemistry, manufacture of varnishes and paints, oil refining and food industry use a lot of organic substances that get into the atmosphere in different ways (Miao et al., 2005; Chetpattananondh et al., 2005).

The majority of air pollutants can remain in the environmental air for a long time, while air masses transfer them far away from the sources of origin (Kleinheinz, Bagley, 1998; Baltrėnas, Paliulis, 2002). Air pollution preconditions climatic changes, worsening of the city air quality, formation of trophospherical ozone, a higher acidity of soil and surface water as well as occurrence of eutrophication. Consequently, this has an adverse effect on human health, agricultural productivity, biological variety and condition of forests (Zhang et al., 2002).

Apart from that, specific unpleasant smells are characteristic of volatile organic compounds. Therefore, attempts are made to discover ways of how to eliminate these bad smells generated in enterprises (Gupta et al., 2001; Shareefdeen et al., 2003).

The absorptive, adsorptive, oxidation and ionization treatment methods are well known globally. However, these treatment methods are distinguished by big capital for operational expenses, they consume much energy to resist bigger hydraulic resistance of the sorbent, while gas containing multi-molecular organic compounds are poorly treated in the air (Jantschak et al., 2004). With the aim to reduce pollution concentrations and avoid an adverse effect on the environment, air cleaning filters utilizing harmful organic substances are used (Deshusses, 1997; Standefer, Willingham, 1998).

Presently, application of biological air treatment method receives increasing attention worldwide by using cheaper, more efficient and ecological biotechnologies. Through the application of this treatment method the mentioned renewable natural sources would be rationally used (Koh et al., 2004; Juneson et al., 2001). Biological air treatment technique is based on the biological destruction of organic compounds by using certain cultures of microorganisms (Yoon, Park, 2002; Ergas et al., 1995). The following bacteria have practical importance on the decomposition of synthetic organic compounds: *Pseudomonadaceae*, *Bacillaceae*, *Bacteriaceae*. A major practical importance is attached to the bacteria of the *Pseudomonas* genus. The *Pseudomonas* genus bacteria can be found on various plants, inside their pollen and vegetable substrates, i. e. branches and stumps. (Tekorienė, Lugauskas, 2001; Raila et al., 2006). Microorganisms in the bio-charge produce enzymes which decompose acetone into non-toxic products – carbon dioxide and water (Chang, Lu, 2003):

$$C_3H_6O + 4O_2 \rightarrow 3CO_2 + 3H_2O \quad (1)$$

In the meantime the energy of oxidation processes and reduced chemical compounds are further used for the growth of

the microorganisms population in the process of biodegradation (Baltrėnas et al., 2004; Baltrėnas, Vaiškūnaitė, 2002). The activity of microorganisms depends on the humidity of the charge, the amount of supplied biogenic elements, and the acidity and temperature of the charge (Fell, 2002).

The aim of this research is to evaluate the use of biological treatment methods to remove acetone from air emissions, and to determine the efficiency of the biological treatment filter by applying a granular charge of fir barks and wood in chips when cleaning the air from acetone that is widely applied in industry.

METHODS

To clean acetone out of the air a biological air purification device, a biofilter 0.5 m long, 0.45 m wide and 2.0 m high, was used. The device consists of five vertically arranged cartridges separated by metal screens from each other. Each cartridge is 0.5 m long, 0.45 m wide and 0.15 m high. The filter's main element is a filtering charge inside the cartridge, which is intended for the maintenance of self-existence of microorganisms. The activated natural biocharge consisting of fir barks and wood in chips was used for the research. The lower cartridges (the first and the second from the bottom) are filled with fir bark cut into pieces of 150 mm long and 70 mm wide, the two cartridges above them are filled with biomedium consisting of wood in chips sized 70 × 150 mm and the same amount of fir bark cut into pieces (composition in percent: 50% of fir bark pieces and 50% of wood in chips). The top cartridge is filled with wood in chips sized 70 × 150 mm (Fig. 1).

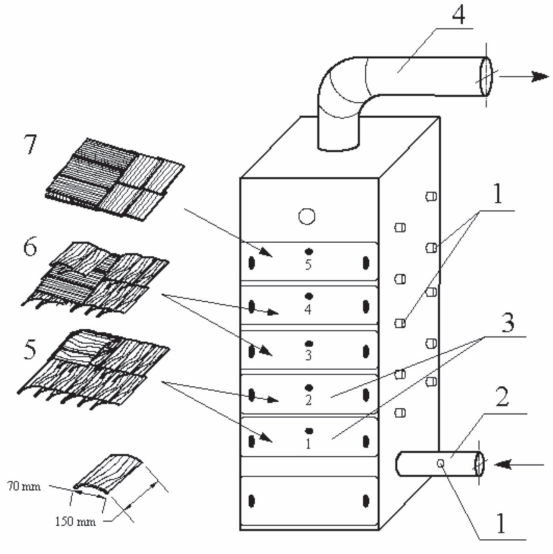

Fig. 1. Stand of the laboratory biofilter. *1* – air sampling holes; *2* – air feeding pipe; *3* – biofilter cartridges; *4* – air discharge pipe; *5* – fir barks; *6* – fir barks and wood in chips; *7* – wood in chips

Prior to setting the biofilter in operation the biomedium is humidified and the humidity of 60% is maintained in it. The humidity is maintained with the help of five pre-installed water sprayers that can humidify each layer of the biomedium separately to maintain an even air flow and ensure run-off of the excess water to the reservoir of excess water. Humidity in the charge is controlled by the method of weighing, i.e. it is heated in the temperature of 105 °C up to until it reaches a constant weight. About 12 litres of water are used to maintain the humidity of the total charge volume (0.18 m^3) per day. To humidify the charge, 2.4 l of water are sprayed on each layer per day. The charge is humidified 2 times per day.

Biodegradation of organic compounds is a rather slow process. In order to speed it up, microorganisms have to be stimulated. It is recommended to fertilize the charge with K, P, N fertilizers (Jankevičius, Liužinas, 2003). To improve the growth and energy of microorganisms, the charge was fertilized with the solution of mineral salts providing microorganisms with vitally important biogenic elements. The solution of salts was made by adding 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, $NaNO_3$ – 0.91 g per 1 litre of water. This solution is poured into a water reservoir and sprayed on each layer of the biomedium (Baltrėnas, Zagorskis, 2005).

The acidity necessary for self-existence of microorganisms in the biomedium, pH = 7.2, is maintained. To maintain the optimum temperature of the granular charge air heaters are installed at the filter walls, which help maintain the constant air temperature of 30 °C in the biofilter (Zigmontienė, Baltrėnas, 2004).

The biomedium was activated for 20 days, afterwards the acetone vapours of different concentrations, i. e. 112, 216, 318, 415, 548 mg/m^3, were supplied to the biofilter. The air flow velocity in the device amounted to 0.3 ± 0.05 m/s. Different concentrations of acetone vapours were obtained by heating this pollutant on an electric stove. The acetone was heated at temperature ranging from 20 to 50 °C.

To determine the concentration of acetone, air samples were taken before biofiltering, between cartridges and after filtering in special sampling places, each sample was taken three times. The sample was extracted from the air duct via a stainless steel tube (d = 5 mm, l = 30 cm) to a clean gas pipette of 0.25 l at the speed of 0.25 l/min. Aspiration lasted for 5 minutes. The acetone concentration was determined by the gas chromatographer SRI 8610 No. 942. The chromatographer sets the following parameters of the analysis process: velocity of nitrogen gas –30 ml/min., velocity of hydrogen gas – 30 ml/min., air velocity – 200 ml/min., the temperature of column thermostat – 100 ± 2 °C.

Aerodynamic resistance of the charge has a major impact on the efficiency of the filter (Pushnov, 2005). Therefore, concentration of pollutants was determined at different air supply speeds. To research dependence of acetone concentration on the velocity of the air supplied, the air flow polluted with acetone was transferred via the biofilter at the following velocities: 0.2; 0.4; 0.6; 0.8 and 1.0 m/s. The air flow velocity in the biofilter was controlled by the air flow control valve installed in the air duct. The acetone concentration fed into the device amounted to 318 mg/m^3. For air sampling and airflow velocity measurements, sampling branches with screw-caps were installed in front of and behind each cartridge. The airflow velocity was measured by the Testo 400 anemometer of the German firm TESTO. The permissible error for the airflow velocity (v) is ± (0.05 + 0.025 v) m/s at temperature ranging from 20 to 70 °C. The probe has a spherical end, ϕ 2.5 mm.

RESULTS AND DISCUSSION

The research findings given in Fig. 2 show that the highest decrease in the pollutant concentration was noticed in the first layers of the

charge, which consisted of activated fir barks. Such a reduction in pollutants is predetermined by a higher porosity coefficient of fir barks compared to wood in chips, which account for 60% and 50%, respectively. When the coefficient of porosity is higher, the charge is better humidified, resulting in more favourable conditions for the development of microorganisms (Fig. 2).

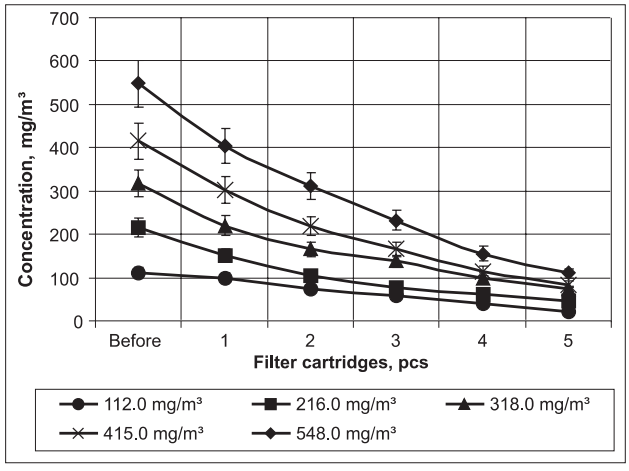

Fig. 2. Change in acetone concentration when using cartridges with different charges at the same time

Having passed through the first two layers of the biocharge, the concentration of acetone decreases from 112.0 to 72.9 mg/m^3, i. e. by 35%. Having increased the concentration supplied to the device up to 548 mg/m^3, after passing through two layers filled with fir barks concentration decreases to 312 mg/m^3 or by 43%. Consequently, the increase in the supplied acetone concentration results in the manifestation of better cleaning properties of the charge filled with fir barks. It can be assumed that the decrease in concentration was predetermined by the fact that with the increase in degraded pollutants the amount of microorganisms also grows, thus improving the cleaning efficiency of the device.

Depending on the original concentration of the supplied pollutant, the third and fourth layers of the activated charge reduced concentration by 39–50 mg/m^3. A somewhat worse cleaning capacity was predetermined by the fact that the charge consisted of fir barks and wood in chips having a lower porosity and a smaller specific surface, however, use of wood in chips would extend the durability of the charge.

Having passed through the fifth layer consisting of wood in chips only, the concentration was reduced by another 25–26%.

It is especially important to evaluate aerodynamic processes within the biofilter. One of the most important features of the device is the filter capacity. In order to enhance the capacity of the device it is necessary to either increase the velocity of the supplied airflow or enlarge the operational area of the charge layer. It is important to determine the dependence of the device cleaning efficiency on the velocity of the supplied airflow. During the experimental research the velocity of the supplied airflow was changed from 0.2 to 1.0 m/s. The original acetone concentration amounted to 318 mg/m^3.

The research findings given in Fig. 3 show that with the increase of the supplied airflow velocity the cleaning efficiency of the biofilter decreases. The highest decrease in the acetone concentration was noticed in the 1st–4th layers of the charge (Fig. 3).

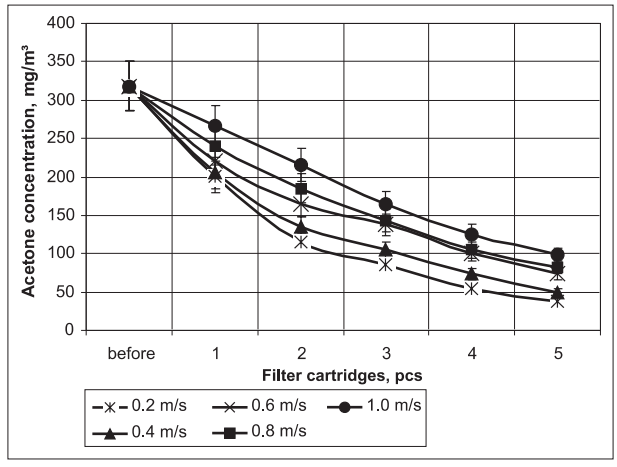

Fig. 3. Dependence of reduction in acetone concentration on the number of charge layers at different velocities of the supplied airflow

When polluted air was supplied to the filter at 0.2 m/s velocity and the original pollutant concentration was 318 mg/m^3, having passed through five layers of the charge filled with activated fir barks and wood in chips the concentration decreased to 38.4 mg/m^3, cleaning efficiency to 87.9%. When the supplied airflow velocity was increased to 1.0 m/s, the acetone concentration decreased from 318.0 to 98.0 mg/m^3. Consequently, when increasing the supplied airflow velocity the cleaning properties of charge decline and at the same time the biofilter cleaning efficiency falls. This happens due to the fact that at a low velocity of the supplied airflow (up to 0.5 m/s) microorganisms in the charge manage to decompose acetone into CO_2 and water. The time of contact of the microorganisms and pollutant in the biofilter amounts to 2 seconds. Upon increasing the velocity of the supplied airflow up to 1.0 m/s the time of contact of the microorganisms living in the charge and the acetone shortens twice, i. e. to 1 second. In order to enhance the cleaning efficiency of the device, it is necessary to reduce the velocity of the airflow supplied to the device (Fig. 4).

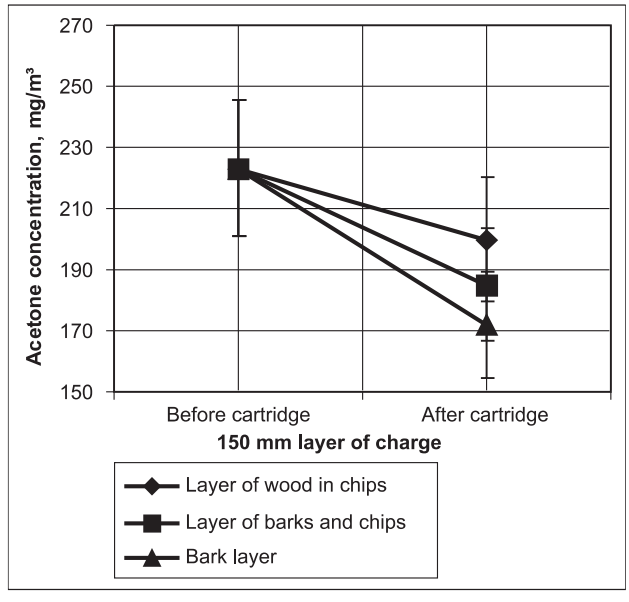

Fig. 4. Reduction of acetone concentration when using different biocharges (velocity of the supplied air reaches 0.3 ± 0.05 m/s)

The findings, given in Fig. 4, show that the highest reduction of the acetone concentration is achieved when using the activated charge consisting of the layer of fir barks. When the charge thickness is 150 mm, the concentration of acetone decreases from 223 mg/m^3 to 172 mg/m^3, while the cleaning efficiency reaches 23%. The lowest cleaning efficiency is reached using the activated charge of wood in chips. The concentration of acetone decreases to 200 mg/m^3.

The decrease in the pollutant concentration is predetermined by lower coefficients of the surface and porosity of wood in chips. In order to extend the durability of the charge, it is suggested to reduce the concentration of acetone by using a blend of the charge consisting of fir barks and wood in chips.

CONCLUSIONS

1. The biggest reduction of the pollutant concentration was recorded in the charges consisting of fir barks. Such a reduction of pollutants is predetermined by a higher porosity of the charge reaching 60%. When the porosity is higher the charge moistens better, resulting in the emergence of more favourable conditions for the development of microorganisms.

2. When the biofilter is supplied with a smaller original concentration of pollutants (112 mg/m^3), an 80% efficiency of the device is achieved. Upon increasing the original concentration, the number of microorganisms using acetone to maintain their energy also increases, therefore, the efficiency of the device practically does not change.

3. When the original pollutant concentration is 318 mg/m^3, and air polluted with acetone is supplied at the velocity of 0.2 m/s, having passed through five charge layers filled with activated fir barks and wood in chips, the concentration of pollutants decreased 88%. Seeking to enhance the cleaning efficiency of the device, it is necessary to extend the time of contact of the microorganisms and pollutant, which has to be no shorter than 2 seconds.

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Pranas Baltrėnas, Alvydas Zagorskis

BIOLOGINIO ORO VALYMO TYRIMAI

S a n t r a u k a

Biologinio oro valymo metodas pagrįstas organinių junginių biologine destrukcija naudojant tam tikras mikroorganizmų kultūras. Metodas nesudėtingas ir gali būti taikomas daugelyje pramonės šakų.

Eksperimentiniams tyrimams naudota aktyvuota įkrova sudaryta iš eglių žievės bei medienos skiedrų. Tyrimais nustatyta, kad didžiausias teršalų koncentracijos sumažėjimas pastebimas biofiltro sluoksniuose, sudarytuose iš eglių žievių įkrovos. Po dviejų 0,30 m storio įkrovos sluoksnių acetono koncentracija sumažėjo apie 50%. Naudojant medienos skiedras acetono efektyvumas sumažėja. Tokį teršalų sumažėjimą lemia 60% poringumo įkrovos sluoksnis. Esant didesniam poringumui įkrova geriau sudrėksta ir atsiranda palankesnės sąlygos mikroorganizmų vystymuisi. Geriausiomis valymo savybėmis įkrova pasižymi tuomet, kai oro srautas į įrenginį tiekiamas nedideliu 0,2 m/s greičiu, nes esant mažam greičiui pailgėja užteršto oro sąlyčio su bioįkrova laikas. Siekiant pailginti įkrovos tarnavimo laiką siūloma orą valyti naudojant eglės žievių ir medienos skiedrų mišinį. Tyrimai parodė, jog biologiniam oro valymui naudojant eglių žievių ir medienos skiedrų mišinį, įkrovos valymo efektyvumas pakinta nežymiai ir pailginamas bioįkrovos tarnavimo laikas.

Raktažodžiai: biofiltras, biodestrukcija, acetonas, mikroorganizmai