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Influence of biofilter's temperature regimes on air cleaning

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Microorganisms cultivated in the biofilter in the course of air cleaning depend on ambient ecological factors that have impact on organism development, procreation, oxidation of pollutants etc. Among the major ecological factors that predetermine the activity of microorganisms in the filter and air cleaning quality are temperature and volatile organic compounds passing the filter. When working on this paper the following research was carried out: assessment of the efficiency of the biofilter by varying the temperature range of the charge (7, 14 and 28 °C) and initial concentrations (up to 100 mg/m^3) of pollutants in question (butyl acetate, butanol and xylene). Air cleaning efficiency depends on the filter charge temperature and pollutant nature. For example, when initial concentrations of butyl acetate and butanol are below 30 mg/m^3 and that of xylene is below 21 mg/m^3, pollutants are removed with an efficiency of 59–77%. However, with the increase of concentrations the efficiency of air cleaning drops down (from 76–77% to 39–41%). At different temperature regimes (7 and 14 °C), the air cleaning efficiency at higher temperature (14 °C) passing through the charge is 5–10% higher. With the temperature of 28 °C maintained, the filter efficiency was much higher. For example, when the initial butanol and butylacetate concentrations were 94 mg/m^3, the air cleaning efficiency was 77–78 %; and when the initial concentration of xylene was 98 mg/m^3, the cleaning efficiency was 53 %.

Key words: biofilter; biocharge temperature; temperature regimes; volatile organic compounds; association of natural microorganisms; biochemical reaction

INTRODUCTION

In Lithuania, as in many other countries, pollution of residential and working environment is one of the key environmental issues. The main sources of air pollution by volatile organic compounds are furniture manufacture, varnish, paint, food, plastic production, oil refineries, etc. Generally, in Lithuania the following hydrocarbons are found in the air at industrial enterprises: benzene, toluene, xylene, isomers et al., which could be removed with the help of biofilters with the activated pine bark charge (Baltrėnas et al., 2002, 2003, 2004). In practice, construction of biofilters is not complicated, moreover, their capital and maintenance costs are low while the period of service is rather long (up to 10 years). These filters have a rather large area of bio-medium with 40–60% porosity which is full of microorganisms. All this helps to achieve high air cleaning efficiency (up to 90–99%) (Krishnayya et al., 1999; Wani et al., 1999; Cox et al., 1998).

Microorganisms cultivated in the biofilter in the course of air cleaning depend on ambient ecological factors that have impact on organism development, procreation, oxidation of pollutants etc. Therefore, filter microorganisms and at the same time biological air cleaning process are affected by a range of physical, chemical and biological elements, charge humidity, pH etc. (Ottengraf et al., 1995; Mcnevin et al., 2000; Mpanias et al., 2000). Among the major ecological factors that predetermine the activity of microorganisms in the filter and air cleaning quality are temperature and volatile organic compounds passing the filter. The above mentioned ambient factors cause changes in the composition and structure of substances in the cells of microorganisms and at the same time the speed of reactions occurring in bio-chemical processes. The impact of the charge temperature on the biological cleaning process and the pollutants in question will be revealed by appropriately chosen analysis methods and their results.

Ecological factors in question not only have an impact on the efficiency of air cleaning by biofilter but also determine the possibilities of filter application in practice.

The aim of the paper is to assess the efficiency of the biofilter by varying the temperature range of the charge (7, 14 and 28 °C) and initial concentrations (up to 100 mg/m^3) of pollutants in question (butyl acetate, butanol and xylene).

MATERIALS AND METHODS

Using the developed biofilter with the activated pine bark the experimental tests have been carried out at the Department of Environment Protection of Vilnius Gediminas Technical University. The biofilter (0.5 × 0.48 × 2.0 m) with a biologically activated charge contains five separate layers of bio-medium which do not press each other, are separated by meshes and ensure even distribution of air flow. The experimental device contained five separate 0.15 m high layers instead of containing a single 0.75 m high layer. The cleaned air is exhausted from the filter through the flexible exit air duct.

Three different temperature regimes were used in the filter charge: 7, 14 and 28 °C. The necessary temperature was achieved by heating bio-medium at the side walls of the filter with the help of two heating elements. The filter contained a temperature regulator with a sensor, which kept the necessary constant temperature regime in the biomass.

During testing, the charge temperature was measured with the help of the TESTO-452 measuring instrument containing a thermocouple. To set the temperature in the charge as accurately as possible, the temperature was measured on the surface of each layer (up to 50 mm deep) and deeper (from 50 to 150 mm). The points for temperature measuring were determined in the following way: perpendicular lines were drawn from the reverse sides of the filter charge, and the intersections of those lines were used as the above mentioned points. At the same point (every 50 mm to horizontal and vertical direction), each measurement was repeated 5 times. The total number of measuring points in each charge layer was 43; the total number of points in all the five layers was 215. A greater number of measuring points ensured a higher reliability of the statistical data.

Prior to starting the biofilter, the medium was moistened, biogenic elements were added and it was biologically activated by blowing organic pollutants through the medium. For natural microorganisms to live in the biologically activated pine-bark charge, it was necessary to maintain concentration of hydrogen ions close to the neutral value (pH = 7.2).

Experimental testing revealed the efficiency of the filter by changing volatile organic compounds of different composition (butanol, bitylacetate, xylene), their initial concentrations, airflow velocity, and the height of charge layers. To compare pollutant biodegradation in the activated pine bark charge, six different concentrations up to 100 mg/m^3 were taken approximately every 15–20 mg/m^3. Different concentrations of organic substances were obtained by heating them at a point in a regulated electric range. Temperature of the airflow injected into the equipment varied in the range of 20–55 °C, therefore, the temperature maintained in the charge had to be increased by several degrees.

Air samples before and after the filter and after each layer were taken at measurement points by using the glass-type pick-up tubes (Ø 4.0 ± 0.1 mm, length 7.0 ± 0.01 m) filled with activated coco carbon (0.3–0.85 mm) produced by the SKC company and the Airchek 224-PCXR8 personal sampler for 15 min at 0.2 l/min velocity. Concentration of compounds under investigation in the air samples was determined by chromatography. The Hewlett Packard Model 5890 gas chromatograph was used. After determining the concentrations of organic substances under investigation by chromatographic analysis, efficiency of the biologic air purifier was calculated.

RESULTS

The filter efficiency depends on the temperature maintained in the charge. This fact was proved by the experimental testing when different concentrations (up to 100 mg/m^3) of the selected pollutants (butyl acetate, butanol, and xylene) were injected into the device at different temperature regimes (7, 14 and 28 °C). Depending on the maintained temperature, microorganism groups of mesophyles and psychrophyles were cultivated in the charge.

Measuring of the filter efficiency was accompanied by the tests on biocharge temperature. Depending on the maintained temperature regime, temperature was measured on different layers of the charge and at different depths of the layers. First of all, tests were performed in the filter charge with the temperature regime of 7 °C. Then tests were performed with the charge temperature of 14 and 28 °C.

First of all, the biofilter efficiency was tested at the temperature of 7 °C. During testing, concentrations of organic pollutants were gradually increased (from 3 to 100 mg/m^3). When rather low concentrations (up to 30 mg/m^3) of compounds in question pass through the filter, the efficiency of butanol and butyl acetate removal from the air is 73–77% (Figs. 1, 2). When pollutant concentrations are increased (to 100 mg/m^3), the efficiency of biological air cleaning depends on the decrease of butanol and butyl acetate (76–77% and 59–60%). For comparison, oxidation of xylene was slower, as it was to a lesser extent dissociated by microorganisms. When the initial concentrations of this pollutant were 21 mg/m^3, the filter was functioning at the efficiency of 59% (Fig. 3). After increasing the initial concentrations of xylene to 95 mg/m^3, the efficiency of air cleaning after passing five charge layers was only 39–41%. Thus, when the temperature is maintained at 7 °C, and the initial concentrations of the pollutant are with slower microbiologic decomposition to 100 mg/m^3, xylene removal efficiency went down by 30%, on average.

The charge temperature was increased to 14 °C, and the efficiency of removal of butyl acetate, butanol and xylene from the air was tested. Comparison of different temperature regimes maintained in the charge (7 and 14 °C) revealed that the efficiency of removal of all the pollutants in question (butanol, butyl acetate and xylene) at a higher temperature (i. e. at 14 °C) went up

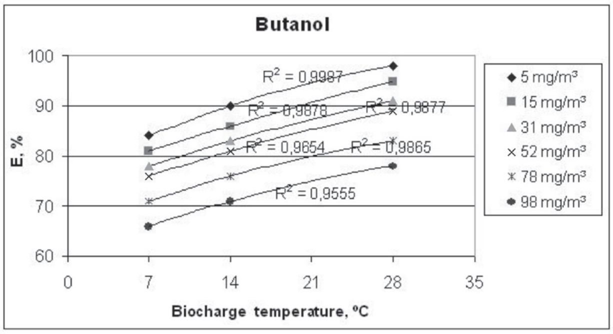

Fig. 1. The efficiency of air cleaning from butanol after the air passed five layers of the filter at the air flow of 144.69 m^3/h, depending on the biocharge temperature

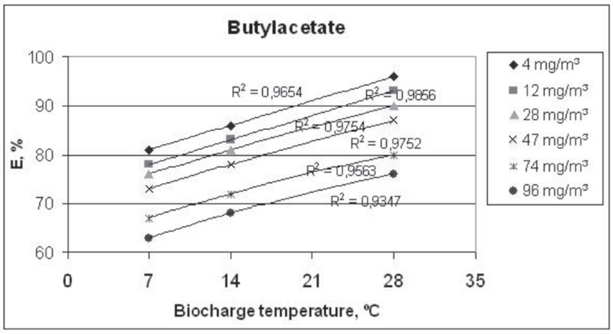

Fig. 2. The efficiency of air cleaning from butyl acetate after the air passed five layers of the filter at the air flow of 144.69 m^3/h, depending on the biocharge temperature

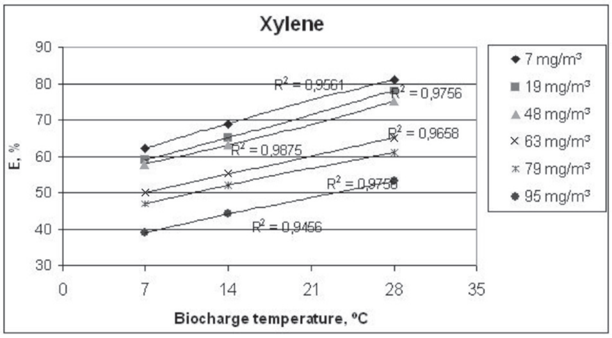

Fig. 3. The efficiency of air cleaning from xylene after the air passed five layers of the filter at the air flow of 144.69 m³/h, depending on the biocharge temperature

by 5%, on average. This fact was proved by experimental testing. For example, when the charge temperature is 7 °C, and the initial concentration of butanol in the filter is 45 mg/m³, the efficiency of pollutant removal is 69%. Whereas, at the charge temperature of 14 °C, the efficiency of air cleaning from butanol (with its initial concentration of 46 mg/m³) was 74%. Similar test results were received while experimenting with the other pollutants tested: butyl acetate and xylene. When low concentration pollutants (up to 30 mg/m³) pass the filter at the temperature of 14 °C, the cleaning efficiency of the air passing through five layers of the charge is 64% (xylene), and 82% (butyl acetate). When concentrations of the above mentioned pollutants were increased to 100 mg/m³ and the same conditions were maintained in the filter, the efficiency of air cleaning from xylene was 44% and cleaning from butyl acetate was 65%.

At the temperature of 28 °C in the filter charge, similar tests were carried out on the shift of the filter efficiency applying different initial concentrations of pollutants of different chemical nature (butyl acetate, butanol and xylene). The latter tests revealed that the filter efficiency results were much higher than those in the previous tests when the temperature of 7 and 14 °C was maintained in the filter. For example, when concentrations of pollutants in the filter were 30 mg/m³, the air cleaning efficiency went up by 19–18%, on average (Figs. 1–3). When the initial pollutant concentrations were increased to 100 mg/m³, the air cleaning efficiency was on average 13–14% higher. When the initial butanol concentration was 94 mg/m³, the air cleaning efficiency was 78%, respectively; when the initial concentration of butylacetate was 95 mg/m³, the cleaning efficiency was 77%; and when the initial concentration of xylene was 98 mg/m³, the cleaning efficiency was 53% (Figs. 1–3).

Considering the capacity of microorganisms to oxidize pollutants in question, it could be stated that the highest efficiency of this process is achieved when the temperature of 28 °C is maintained in the charge. Analysis of individual pollutants and biological degradation of their concentrations revealed that oxidation of water-soluble compounds (butyl acetate and butanol) by microorganisms living in the filter charge was more intensive; and that of less water-soluble and slowly biodegrading compounds, such as xylene, was less intensive. Degradation of pollutants with the initial concentrations relatively low (up to 30 mg/m³) is easier and more efficient, i. e. test results of different initial concentrations differ only by several percent. A greater difference between efficiency results is observed when pollutants passing the filter are of higher concentrations (from 30 to 100 mg/m³), and lower temperature regime (7 and 14 °C) is maintained in the biocharge.

CONCLUSIONS

Applying different temperature regimes (7, 14 and 28 °C) of the filter charge, temperature variation dynamics depending on the microorganism group, velocity of biochemical reactions, temperature of the injected air flow and initial pollutant concentrations, was recorded.

Air cleaning efficiency depends on the filter charge temperature and pollutant nature. For example, when initial concentrations of butyl acetate and butanol are below 30 mg/m³ and that of xylene is below 21 mg/m³, pollutants are removed with the efficiency of 59–77%, when concentrations are increased, the efficiency of air cleaning drops down (from 76–77% to 39–41%).

When low concentration pollutants (up to 30 mg/m³) pass the filter at different temperature regimes (7 and 14 °C), the cleaning efficiency of the air passing through the charge is 5% higher, i. e. in the case of xylene it is 64%, and in the case of butyl acetate and butanol it is 82%. When the initial concentrations of pollutants were increased to 100 mg/m³, the efficiency of air cleaning from xylene was 44%, and that from butyl acetate and butanol was 65%.

With the temperature of 28 °C maintained, the filter efficiency was much higher. With the initial pollutant concentrations equal to 30 mg/m³, the cleaning efficiency increased by 18–19%. When the initial pollutant concentrations were increased to 100 mg/m³, the air cleaning efficiency was 13–14% higher, on average. For example, when the initial butanol and butyl acetate concentrations were 94 mg/m³, the air cleaning efficiency was 77–78%, and when the initial concentration of xylene was 98 mg/m³, the cleaning efficiency was 53%.

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References

1. Baltrėnas P., Vaiškūnaitė R. 2004. A biofilter containing a biologically active layer of pine bark for removing volatile hydrocarbons from air. *Chemical and Petroleum Engineering*. Vol. 40. No. 7. P. 417–420.
2. Baltrėnas P., Vaiškūnaitė R., Špakauskas V. 2004. Experimental study and mathematical modelling of biofilter aerodynamic resistance. *Journal of Environment Engineering and Landscape Management*. Vol. XII. No. 3. P. 79–84.
3. Baltrėnas P., Vaiškūnaitė R. 2003. Microbiological investigation of activated pine-bark charge for biofilters. *Journal of Environment Engineering and Landscape Management*. Vol. XI. No 1. P. 3–9.
4. Baltrėnas P., Vaiškūnaitė R. 2002. Biological air purification by using activated pine bark charge. *Environmental Engineering*. Vol. X. No 2. P. 70–76.
5. Krishnayya A. V., Agar J. G., Wrong T. T., Nevokshonoff B., Warren R. 1999. Temperature effects on biofiltration of

off-gases. *Journal Environmental Science-Health*. Vol. 12. No. 1. P. 186–195.

6. Wani A. H., Brarion R. M. R., Lau A. K. 1999. Biofiltration: a promising and cost-effective control technology for odors, VOCs and air toxics of off-gases. *Journal Environmental Science-Health*. Vol. 7. No 32. P. 2027–2055.
7. Cox H. H. J., Deshuses M. A. 1989. Biological waste air treatment in biotrickling filters. *Current Opinion in Biotechnology*. Vol. 9. P. 256–262.
8. Ottengraf S. P. P., Oever A. H. C. 1995. Kinetics of organic compound removal from waste gases with a biological filter. *Biotechnology and Bioengineering*. Vol. 1. No. 121. P. 21–33.
9. Mcnevin D., Bardorf J. 2000. Biofiltration as an odour abatement strategy. *Biochemical Engineering Journal*. Vol. 5. No. 120. P. 231–242.
10. Mpanias C. J., Baltzis B. C. 2000. An Experimental and modelling study on the removal of mono-chlorobenzene vapour in biotricling filters. *Biotechnology and Bioengineering*. Vol. 3. No. 59. P. 328–343.

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BIOFILTRO TEMPERATŪROS REŽIMO REIKŠMĖ ORO VALYMUI

Santrauka

Oro valymo metu biofiltre kultivuojami mikroorganizmai labai priklauso nuo aplinkos ekologinių veiksnių, kurie turi įtakos gyvų organizmų vystymuisi, dauginimuisi, gebėjimui oksiduoti teršalus ir pan. Vieni svarbiausių filtro mikroorganizmų aktyvumą ir oro valymo kokybę sąlygojančių ekologinių veiksnių yra temperatūra bei tyrimų metu per filtrą leidžiami lakieji organiniai teršalai. Darbo metu įvertintas biofiltro efektyvumas, keičiant jo įkrovos temperatūros režimą (7, 14 ir 28°C) leisti skirtingu pradinių koncentracijų (iki 100 mg/m^3) tiriamieji teršalai (butilacetatas, butanolis ir ksilenas). Oro valymo efektyvumas priklauso nuo filtro įkrovos temperatūros ir teršalų kilmės. Pavyzdžiui, kai įkrovos temperatūra 7°C bei pradinės butilacetato, butanolio koncentracijos iki 30 mg/m^3, o ksileno iki 21 mg/m^3, teršalų valymo efektyvumas 59–77%, padidinus koncentracijas valymo efektyvumas sumažėja (nuo 76–77 iki 39–41%). Palyginus įkrovoje palaikomus temperatūros režimus (7 ir 14°C), esant aukštesnei kaip 14°C temperatūrai, oras išvalomas 5–10% efektyviau. Bioįkrovoje palaikant 28°C temperatūrą, gautas gerokai didesnis filtro efektyvumas. Pavyzdžiui, dėl butilacetato ir butanolio, kurių pradinės koncentracijos 94 mg/m^3, oro valymo efektyvumas net 77–78%.

Raktažodžiai: biofiltras, bioįkrovos temperatūra, temperatūros režimai, lakieji organiniai junginiai, savaiminė mikroorganizmų asociacija, biocheminė reakcija