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INVESTIGATION OF EFFICIENCY OF CASSETTE BIOFILTERS, DESIGNED FOR AIR CLEANING FROM XYLENE

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Abstract. The experimental investigations were carried out, using the biofilter *BIOF-I* with the system of III cleaning stages, loaded with charge, composed of zeolite granules, wood chips, barks and foam, as well as the biofilter of II cleaning stages *BIOF-II*, loaded with the mixture of zeolite and wood barks. When mixing the zeolite granules with wood barks for air cleaning from xylene, not only biological, but also adsorptive air treatment method is used. Applying the complex cleaning technologies, the effectiveness of equipment cleaning as well as the life cycle of charge is improved. Cultivating the associations of spontaneous microorganisms in the charge, the dependence of cleaning efficiency of biofilters on the concentration of supplied pollutant and the speed of air flow was determined. When cleaning air from xylene with the initial concentration of pollutant equal to 120±5 mg/m^3, the efficiency of filters *BIOF-I* and *BIOF-II* was 94 %. The air cleaning efficiency of biofilters increases, when reducing the speed of supplied polluted air flow. In case of reducing the air flow speed from 0.3 to 0.1 m/s, the efficiency of biofilters *BIOF-I* and *BIOF-II* increases from 75 to 83 % and from 75 to 84 %, respectively.

Keywords: biofilter, biocharge, xylene, microorganisms.

1. Introduction

Many of volatile organic compounds (VOC), discharged to the atmosphere, may be harmful to human health. They damage the wildlife, have toxic impact and the direct influence on climatic change and formation of greenhouse effect (Delhomenie and Heitz 2005).

In the industry branches of chemistry, varnish and paints a lot of organic materials, which pass into the atmosphere in different ways, are used. Among the most common organic compounds there are acetone, butanol, toluene, xylene, etc. Due to volatile organic compounds, released into the atmosphere because of human activity, photochemical oxidants are formed, the high concentration of which is harmful for human health, damaging for flora and the environment in general (Paulauskienė *et al.* 2009).

One of the most effective, simplest and cheapest technologies, by the usage of which the air is treated from volatile organic compounds is air flow cleaning using biofilter (Žarnauskas 2008).

Biofilters are used for air cleaning from butanol, acetone, xylene, toluene and other VOCs. The equipment is effective, when the concentration of pollutant does not exceed 500 mg/m^3 (Baltrėnas and Zagorskis 2010).

One of the most important elements of biofilters, ensuring the biological process of air cleaning, is biocharge. The nature of biocharhe, porosity, humidity, pH, temperature, adsorptive and absorptive characteristics determine the growth and evolution of population of microorganisms, thus ensuring the efficient air flow cleaning in biofilter (Žarnauskas 2008).

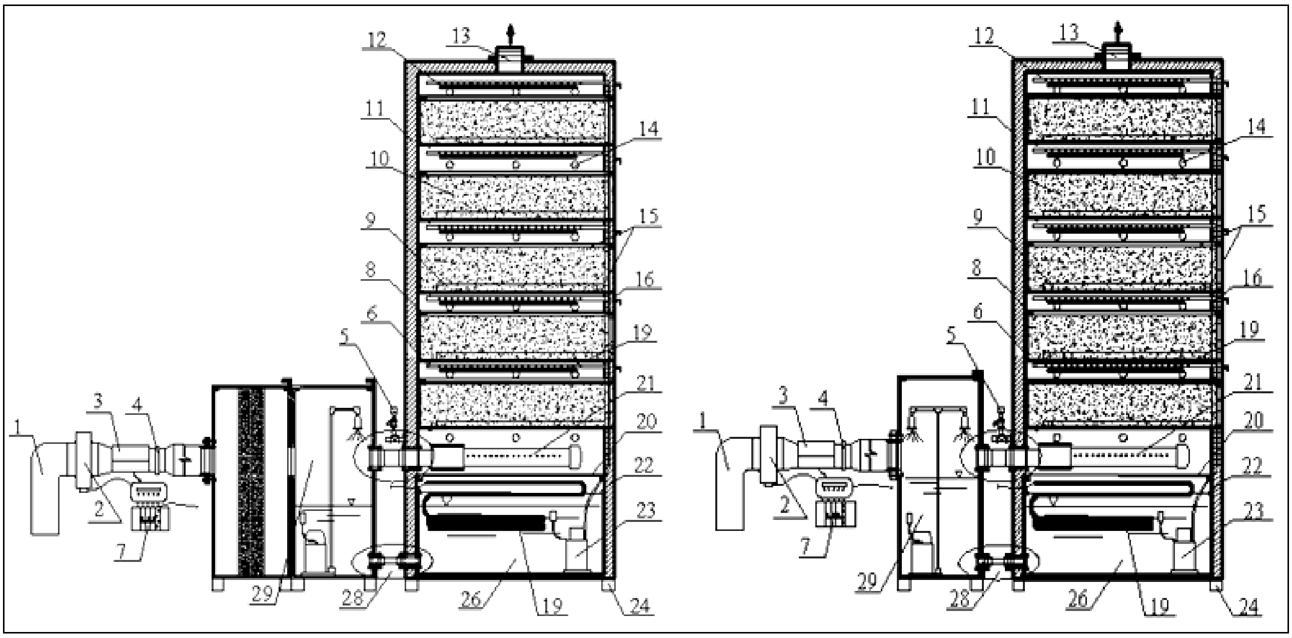
Seeking to prolong the life cycle of charge of biofilter and at the same time to improve the efficiency of equipment, biological and adsorptive methods could be applied together. By combining the aforementioned methods, the high degree of volatile organic compounds' cleaning is achieved (Baltrėnas and Zagorskis 2010).

Zeolite is widely used as an adsorbent due to large useful surface area, porosity, ensuring a good sorption of pollutants. When mixing the zeolite granules with wood barks for air cleaning from volatile organic compounds, both biological and adsorptive air cleaning methods are used (Jeong *et al.* 2009).

The aim of the present study is to determine the dependence of cleaning efficiency of biofilters on the concentration of supplied pollutant and the speed of air flow by cultivating the associations of spontaneous microorganisms in biocharges.

2. Methods

Experimental investigations were carried out, using cleaning biofilters of two and three stages, i.e., *BIOF-I* and *BIOF-II* (Fig 1).



a) b)

Fig 1. Stands of biofilters: a) *BIOF-I* – biofilter prototype with irrigation chamber and air distribution collector; b) *BIOF-II* – biofilter prototype with the system of three cleaning stages

The main element of filters is the filtrating activated charge, made from zeolite granules, foam cubes and wood chips (Fig 2).

a) b)

Fig 2. Biofilter packing materials: a) mixture of wood chips, barks and foam cubes; b) mixture of wood chips, barks and zeolite granules

Each filter has five cassettes, which are separated from each other with metal sieves – thus, the even distribution of air flow and humidity through the whole layer of charge is ensured and the aerodynamic resistance of charge is reduced. In order to carry out investigations, each biofilter was loaded with different packing materials.

Biofilter *BIOF-I* was loaded with the mixture of wood chips, zeolite granules and foam cubes. The mixture ratio of materials was 33:33:34 %, according to volume. Biofilter *BIOF-II* was loaded with the mixture of wood chips of 20–30 mm fraction and natural zeolite granules of 10–15 mm size. The mixture ratio of chips and granules, according to volume was 50:50 %.

The length of each of five cassettes, loaded with packing materials, was equal to 0.85 m, the width was 0.65 m, and the height – 0.15 m.

After filling the cassettes, the charge had been activated, maintaining 30 °C temperature, the acidity of biomedium pH=7 and the concentration of biogenic elements.

Before starting the biofilters the charge was irrigated by water nozzles, equipment above each layer. The water, saturated with biogenic elements, was supplied to nozzles by the pump, equipped in the tank of excess water. During investigations the humidity of 75 % was maintained in the charge.

Xylene polluted air is supplied to each biofilter by the ventilator 2, equipped in air duct 1. In order to maintain the activity of microorganisms, the polluted air in biofilters is heated by duct heaters 3, which regulate the temperature of air, supplied to equipment. For adjustment of air flow speed there are air flow speed adjustment valves 4. For the maintenance of required humidity of the charge the branch pipe of saturated water supply with valve is equipped 5. Perforated pipes 6, designed for irrigation of the charge, are laced and secured with holders 12 above each layer of the charge 10. Water, saturated with biogenic elements, is supplied from water tank 26 by pump 23 and rubber hose 16 to perforated pipes 6. The water tank is protected from pollution by sieve 20 and ducts 22. Control panels 7 are equipment in biofilters, which allow adjustment of required air temperature and the intensity of charge irrigation. In order to maintain an equal distribution of air through the whole layer of charge, sieves 15 with frame 8 and collectors 21 are equipped in the cassettes. Biofilter cassettes are held by angles 9, fixed in filter walls 11. For removal of the cleaned air there are air removal ducts 13. For the measurement of physical parameters and taking the air samples branch pipes 14 are equipped in the sides of filters. There are heating cables 19 under the cassettes in biofilters, which heat the charge, even if a ventilator 2 does not work. Air flow irrigation chambers 29 are linked with biofilter with connectors 28. The construction of biofilters is stood on the stands 24, equipped at the bottom of filters (Zagorskis 2009).

Xylene vapour concentration before five layers of packing materials of biofilters was 120±5 mg/m^3. In order to determine the concentration of pollutant, air samples were taken, maintaining the constant speed of the supplied air flow, equal to 0.1 m/s. Then the speed of the supplied air flow was increased to 0.2 m/s, using the adjustment valve, equipped in each biofilter. Investigations were repeated by increasing the speed of the supplied air flow to 0.3 m/s.

The speed of fed air flow and temperature was measured by device "*Testo 400*" of German manufacturer "*Testo"* during charge.

In order to determine the dependence of efficiency of biofilters on the initial concentration of pollutants, the concentration of xylene vapour was increased to 200 ± 5 mg/m^3. Pollutant concentration was changed by heating it on electric stove. Then the investigations were repeated with the increased concentration of xylene to 310±5 mg/m^3.

Xylene concentration was measured by device "*MiniRae – 2000*", manufactured by American company "*RaeSystems"*, the measurement limits of which are from 0 to 7000 mg/m^3. Measurement accuracy, when pollutant concentration is from 0 to 100 mg/m^3, is 0.1 mg/m^3, and when pollutant concentration exceeds 100 mg/m^3 – 1 mg/m^3.

3. Results and discussion

After completing the experimental investigations, the dependence of air treatment efficiency of biofilters on the concentration of pollutant vapour, supplied to equipment, and the speed of polluted air, was received.

The investigations of dependence of filter cleaning dependence on the concentration of pollutant vapour, supplied to equipment, were carried out by supplying xylene polluted air to equipment at the speed of 0.1 m/s.

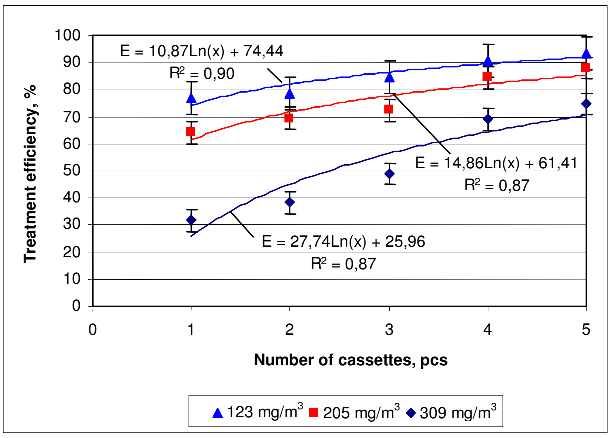


Fig 3. The dependence of air treatment efficiency of biofilter *BIOF-I* on the number of cassettes, in case of different initial concentration of xylene

After measuring xylene concentrations before and after each cassette, the efficiency of cleaning biofilter of three stages was received (Fig 3). The air treatment efficiency of equipment increased most after the first cassette, filled with activated charge of mixture of zeolite, wood chips and barks, and foam. Zeolite has a porous structure and a large area of cleaning surface, therefore, a part of pollutant adsorbs on the charge surface (Zagorskis 2009).

After the first layer, the cleaning efficiency of filter *BIOF-I* reached 32 %, and after all filtrating layers – 94 %. When increasing the concentration of xylene vapour from 123 mg/m^3 to 309 mg/m^3, the cleaning efficiency of filter declined to 75 %. When increasing the concentration of pollutant, equipment efficiency declines, since the microorganisms do not have enough time to decompose the pollutant completely.

When increasing xylene concentration the cleaning efficiency of equipment was declining. The efficiency of cleaning biofilter of II stages increased most after the first cassette, filled with the charge of wood chips, barks and natural zeolite (Fig 4). Up to 40 % of pollutants are decomposed at this layer (Zagorskis 2009).

Xylene was decomposed best, when its initial concentration was lower. When the initial concentration of xylene vapour in the equipment *BIOF-II* was equal to 120 mg/m^3, its efficiency after 5 layers of charge was 94 %. After increasing the concentration of xylene vapour to 312 mg/m^3, filter efficiency declined to 75 %.

In order to improve the cleaning efficiency of biofilter in the presence of high (from 500 mg/m^3) concentrations, it is necessary to increase the number of cassettes in equipment or reduce the speed of air flow, supplied to equipment (Zagorskis 2009).

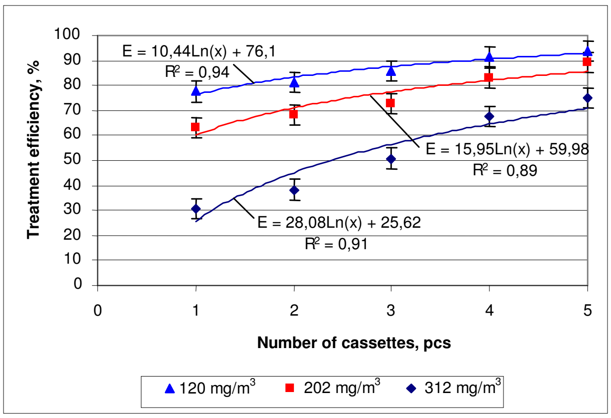


Fig 4. The dependence of air treatment efficiency of biofilter *BIOF-II* on the number of cassettes, in case of different initial concentration of xylene

The cleaning efficiency of biofilters depends on the time of contact of pollutant with charge. Filtration duration is directly proportional to cleaning efficiency of equipment – the longer duration of contact of xylene with charge, the higher filter cleaning efficiency is reached.

The duration of polluted air filtration depends on the speed of air flow, passed through the biofilter. The best efficiency of equipment was reached, when feeding the polluted air through charge at the speed of 0,1 m/s.

Cleaning efficiency of biofilter *BIOF-I* was 75 %, when the speed of polluted air flow was equal to 0,3 m/s. After reducing the air flow speed to 0.1 m/s, the efficiency of biofilter increased to 83 % (Fig 5).

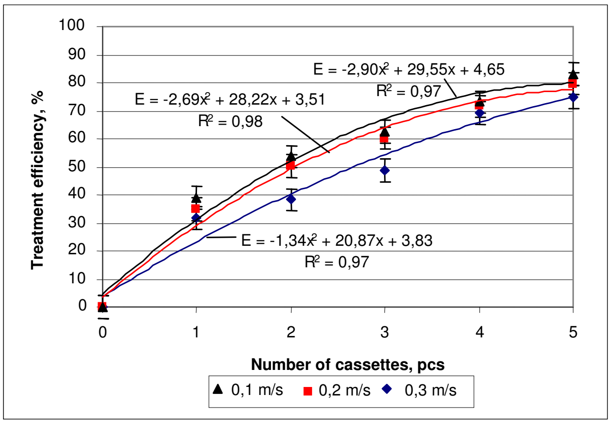


Fig 5. The dependence of air treatment efficiency of biofilter *BIOF-I* on the number of cassettes, when air flow is fed through the equipment at different speed

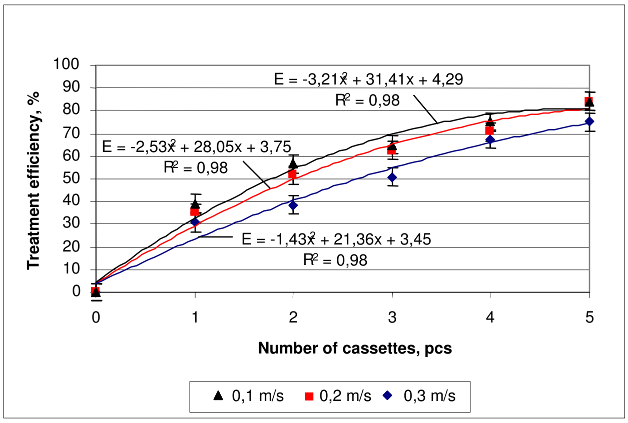


Fig 6. The dependence of air treatment efficiency of biofilter *BIOF-II* on the number of cassettes, when air flow is fed through the equipment at different speed

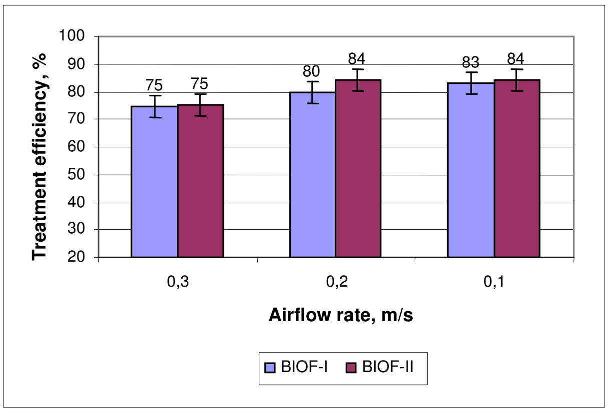


Fig 7. The dependence of air treatment efficiency of biofilters *BIOF-I* and *BIOF-II* on the speed of air flow, fed through equipment

Cleaning efficiency of biofilter *BIOF-II* was 75 %, when the speed of air flow, polluted with xylene vapour, was equal to 0.3 m/s (Fig 6). After reducing the speed of supplied air flow to 0.1 m/s, equipment efficiency increased to 84 %.

Figure 7 shows that cleaning efficiency of biofilters increases, when the duration of biochemical reactions, which take place in them, is longer. It is, when the speed of air flow, supplied to equipment, is lower. When passing the xylene polluted air through *BIOF-I* and *BIOF-II* filters at 0.3 m/s speed, both biofilters generated the efficiency of 75 %. After reducing the air flow speed to 0.1 m/s, the efficiency of biofilters increased to 83 and 84 %, respectively.

Figure 8 shows that the efficiency of biofilters declines, when increasing the concentration of xylene vapour, since the microorganisms do not have enough time to decompose the pollutant completely. In order to increase the efficiency, it is necessary to reduce the air flow speed or increase the number of cassettes in equipment.

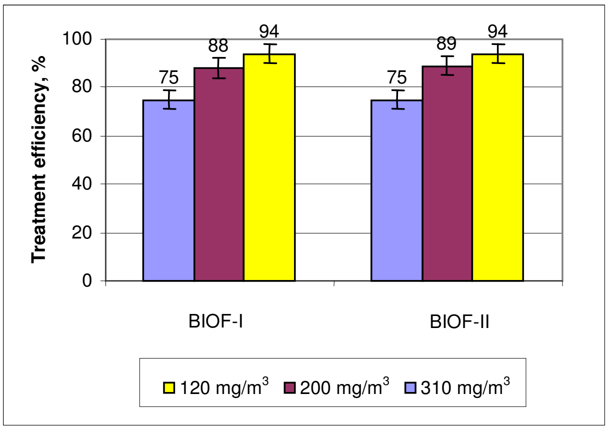


Fig 8. The comparison of air treatment efficiency of biofilters *BIOF-I* and *BIOF-II*, when the concentration of supplied pollutant is 120 ± 5, 200 ± 5 and 310 ± 5 mg/m^3

When supplying the air, polluted with xylene vapour, to biofilters *BIOF-I* and *BIOF-II*, the efficiency of equipment was 94 %, when the concentration of pollutant was 120±5 mg/m^3. After increasing xylene concentration to 310±5 mg/m^3, cleaning efficiency declined to 75 % in both biofilters.

Indian scientists, using the biofilter, loaded with compost, for cleaning the air, polluted with xylene vapour, reached the cleaning efficiency of 60–90 %. French scientists, using the compost charge in biofilter, reached the efficiency of 100 %, when cleaning the air from acetone, and 80 % – from xylene. When using the mixture of compost and pozzolanic ash, the cleaning of air, polluted with xylene vapour, increased to 90 % (Jeong *et al.* 2010).

4. Conclusions

1. When cleaning the air, polluted by xylene vapour, in biofilter with irrigation chamber and air distribution collector and in biofilter with the system of three

cleaning stages, the equal air cleaning efficiency of 94 % was reached.

2. When increasing vapour concentration in the air, supplied to biofilters, their cleaning efficiency declines. After increasing the concentration of pollutant from 123 to 309 mg/m^3, cleaning efficiency of biofilter *BIOF-I* declines from 94 to 75 %. After increasing xylene vapour concentration from 120 to 312 mg/m^3, cleaning efficiency of biofilter *BIOF-II* declines from 94 to 75 %.
3. The air cleaning efficiency of biofilters increases, when reducing the speed of polluted air flow, which is supplied to them. When reducing the air flow speed from 0.3 to 0.1 m/s, the efficiency of biofilter *BIOF-I* increases from 75 to 83 %, and of biofilter *BIOF-II* – from 75 to 84 %.
4. The experimental investigations generated fairly good results, when compared with the papers of foreign scientists: xylene cleaning efficiency in biofilters is 75–94 %, whereas the efficiency of biofilters, used for investigations by scientists from France, India – 60–90 %.

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