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# Usage of active sludge and active carbon suspension in the biological air purification

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A vast variety of air-purification methods are being used worldwide nowadays. The following are the main features determining the choice of a method: a high cleaning efficiency, formation of non-harmful splitting products, and a low price. Biological air cleaning equipment charged with activated sludge is used for cleaning VOC (volatile organic compounds) polluted air. Despite of the equipment's small size, it can clean large amounts of polluted air (around 100 thous. $m^3$). It is convenient to use active carbon and active sludge suspension in the biological air-purification equipment in order to make air cleaning more effective. Owing to its good adsorption coefficient active carbon can be a perfect equivalent of an active sludge in such equipment.

The purpose of this research is to improve the purification efficacy of air-born volatile organic compounds using active carbon and active sludge suspension. The experiments where carried out with three different organic substances: etilacetate, butilacetate and toluene. Data were obtained by substituting organic substances as well as adjusting their concentrations and active carbon mass (concentration).

**Key words**: volatile organic compounds (VOC), biological air purification, active sludge, active carbon, adsorption

## INTRODUCTION

Our idea of human effect on nature has changed markedly since the middle of the 20th century making environmental pollution the problem of nowadays.

Large amounts of organic substances are being released into the atmosphere from different sources annually. Volatile organic compounds are some of them. They are released into the atmosphere from different industrial enterprises: chemical, oil and dye, petroleum refining, and food industry (Zigmontienė et al., 2004). One of the largest air polluters has been various means of transport. The problem of volatile organic compounds is being particularly emphasised lately, as industrial companies are using a large variety of varnishes, dyes, and solvents.

Air-purification methods have been used in order to decrease the concentration of polluting emissions and their harmful effects on the environment. The main features that determine the choice of a method are the following ones: a high cleaning efficacy, formation of non-harmful splitting products and a low price (Zigmontienė et al., 2003). The biological air-purification method has all the above mentioned features. It could be easily used due to its simplicity. It is based on the biodestruction of organic compounds into non-harmful splitting products using certain microorganism cultures (Jakštaitė et al., 1999).

Biological air-purification equipment charged with active sludge is used for purification of air polluted with volatile organic compounds. The equipment is rather simple in design and small-sized, as 1 g of activated sludge contains about $1 \cdot 10^{12}$–$10^{14}$ microorganisms (Zigmontienė et al., 2002).

Using active carbon in addition to the active sludge charge in the biological air-purification equipment seems to make air cleaning more effective. Active carbon is one of the most popular, well-known and widely used adsorbents. The bigger surface area of the hard substance (adsorbent), the better organic compounds absorb into it and adhere to it. A specific surface of active carbon can be as high as 1500 $m^2/g$ (Kirtys et al., 2002). The surface area is determined by adsorbent's porosity (Baltrėnas et al., 2002).

The purpose of these experiments is to analyze the efficacy of biological air-purification equipment using active sludge alone followed by the suspension of active sludge and active carbon as a charge, and substituting organic substances one by one, by etilacetate, butilacetate and toluene.

## MATERIALS AND METHODS

Experiments were carried out using biological air-purification equipment, created and manufactured by the VGTU Environmental Protection Department in 2001 (Bakas et al., 2001). Being of simple design and rather easy in exploitation, the above equipment can be used in chemical, food, oil and dye, as well as in petroleum refining industrial enterprises to neutralise air-born volatile organic compounds.

The equipment consists of a vertical Venturi tube with a confusor, a nick of the tube, a diffuser, a liquid tank connected to the diffuser, a flat drops' separator and a protective net fastened in the upper part of the tank above the diffuser. Active sludge is pumped into the Venturi tube and is brought into contact with the polluted air. A blower is connected to an air-inlet nipple. A damper controls the flow of the supplied air.

Experiments were carried out with the above biological air-purification equipment, using first active sludge alone as a charge followed by suspension of active carbon and active sludge. Active sludge was provided by the Vilnius City Cleaning Facilities. Its sludge coefficient was used as its quality indicator, and the volume estimated occupied by 1 g of ASDM (activated sludge dry material) measured 30 min. after sedimentation. The ideal sludge sedimentation coefficient is 40–120 ml/g. The coefficient of the active sludge used in the experiment was 100–110 ml/g. Dry material mass was 7–9 g/l.

The buffer solution of NaOH or phosphoric acid ($H_3PO_4$) was added to the charge in order to maintain the pH-value required (6–8). The pH of the charge was measured using the pH 538' meter. The temperature of the polluted air entering the equipment during the experiment was 18–20 °C.

Throughout the experiments with active carbon and active sludge suspension, active carbon brought from Vilnius City Cleaning facilities was added to active sludge before the cleaning process: in the first case 500 g of active carbon were added to 40 l of active sludge, in the second case 200 g, in the third case 100 g of active carbon were added.

The common expression of the active carbon specific surface is 1500 $m^2$/g. The following results are obtained after appropriate calculations for each of our three cases: in the first case the active surface area made up estimated 750 thous. $m^2$, in the second case 300 thous. $m^2$, in the third case 150 thous. $m^2$.

Experiments were carried out in laboratory conditions. The airflow at the inlet and outlet nipples was measured by means of the TESTO-452 flow meter.

Organic compound concentrations in both polluted and cleaned air were analyzed using the Cvet 560 M gas chromatograph.

## RESULTS AND DISCUSSION

The research was performed by substituting organic substances, their concentrations and masses (concentrations) of active carbon.

The experiments were carried out with etilacetate, butilacetate and toluene.

The active sludge provided was poured into a tank and oxygenated. The concentration of the oxygenated active sludge required should be above 2 mg/l. It would otherwise slower down or stop the biochemical processes within organic pollutants. The equipment was constantly supplied with air, which would maintain an optimal concentration of the dissolved oxygen.

Active carbon concentration in the active sludge was being changed during the experiments with active sludge and active carbon suspension.

Fig. 2 depicts a graph of dependence of purification on the concentration of organic substances (etilacetate, butilacetate and toluene) entering the equipment with active sludge charge. Using identical air concentrations of 50 mg/$m^3$ for all the substances, the highest purification efficacy (90%) was observed upon the entry of etilacetate into the equipment, butilacetate measured 75%, while toluene purification efficacy was 60%.

Increase in the concentration above 800 mg/$m^3$ and more, decreases the efficacy of the equipment to 65% for etilacetate, 42% for butilacetate, and 30% for toluene. The amount of active sludge present in the biological air-purification equipment is insufficient to oxidize such concentrations of organic substances. These results were also influenced by the concentration of active sludge in the equipment. The toxicity effect has been demonstrated by using a 4 g/l concentration of active sludge and high concentrations of organic substances. The effect is caused by the destruction of microorganisms by organic substances, which decrease microorganism concentration and can eventually inter-

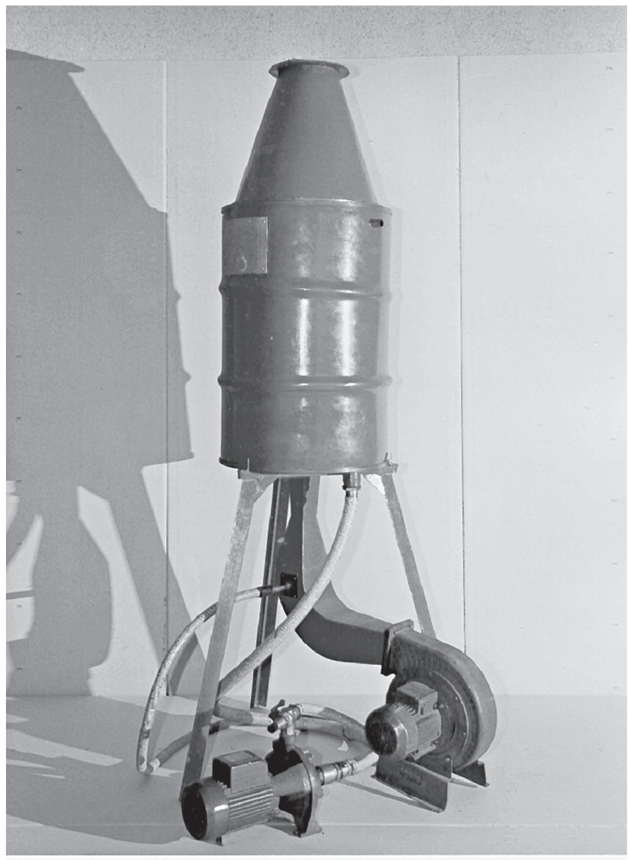

**Fig. 1.** Industrial biological air-purification equipment with active sludge recirculation

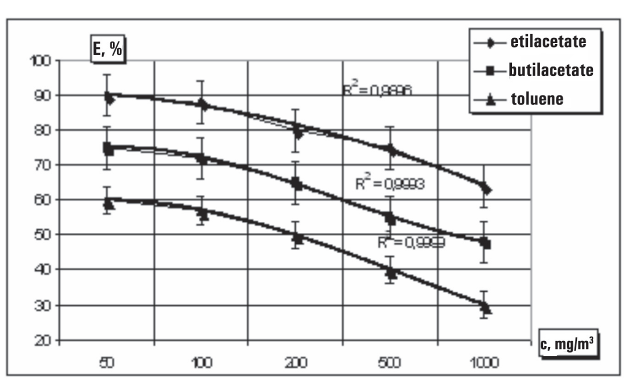


**Fig. 2.** Dependence of purification efficacy on the concentration of organic substances entering the equipment: $c_{activated\ sludge} = 4$ g/l; pH = 6.9; amount of purified air = 300 $m^3$/h

rupt the biodestruction process completely. As active sludge acts as a good absorbent of organic substances, they were absorbed in the water phase.

Increasing efficacy of the air-purification equipment was observed by raising active sludge concentration in the equipment from 4 g/l to 6 g/l and 9 g/l, while using the same concentrations of organic substances (etilacetate, butilacetate and toluene).

In the first case (Fig. 2), where concentration of active sludge used in the equipment was 4 g/l, and concentration of etilacetate entering the equipment was 50 mg/m$^3$, purification efficacy achieved was only 90%, while in the second and third cases (Fig. 3 and Fig. 4), where concentrations of active sludge in the equipment were 7 g/l and 9 g/l, respectively, and concentration of etilacetate was identical, purification efficiency increased to 95% (in the second case) and to 99% (in the third case).

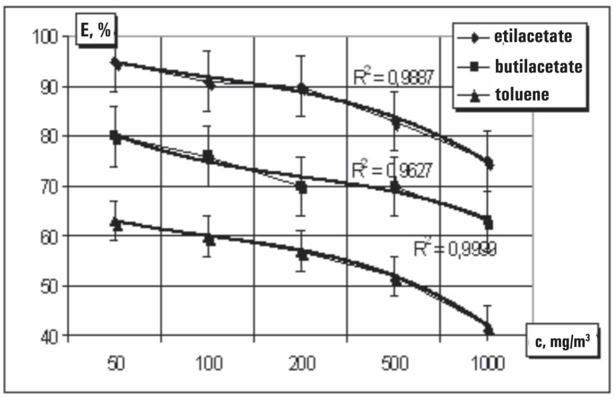


**Fig. 3.** Dependence of purification efficacy on the concentration of organic substances entering the equipment: $c_{activated\ sludge} = 7$ g/l; pH = 6.9; amount of purified air = 300 m$^3$/h

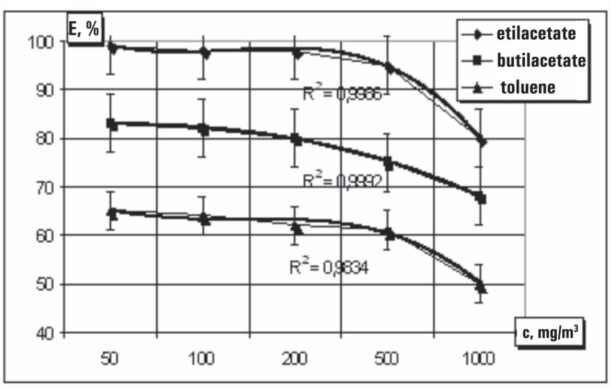


**Fig. 4.** Dependence of purification efficacy on the concentration of organic substances entering the equipment: $c_{activated\ sludge} = 9$ g/l; pH = 6.9; amount of purified air = 300 m$^3$/h

Similar effect was observed during cleaning of the air polluted with butilacetate and toluene. Using concentration of 50 mg/m$^3$ of the above compounds in the air and concentration of active sludge of 9 g/l, the highest purification efficacy observed using butilacetate was 83%, compared to 65% of that with toluene.

To make air cleaning more effective, it is convenient to use not only active sludge charge in the biological air-purification equipment, but also active carbon, which has good adsorption qualities.

As demonstrated in Fig. 5, purification efficacy of the equipment was very high when concentration of 12.5 g/l of active carbon in active sludge was used. The highest purification efficacy reached while cleaning the air polluted with etilacetate was 97%, with butilacetate 95%, with toluene 75%. These results were markedly influenced by the specific surface area of active carbon, which in our case was 750 thous. m$^2$. The larger the surface area of the adsorbent (active carbon), the better is the absorption of organic compounds, and the stronger is their adherence to it.

A decrease in the efficacy of the air-purification equipment was observed, when the concentration of active carbon in the

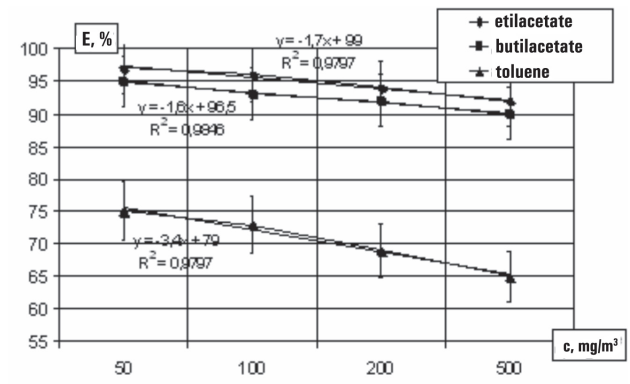


**Fig. 5.** Dependence of purification efficacy on the concentration of organic substances entering the equipment: $C_{active\ sludge} = 4$ g/l; pH = 6.9; amount of purified air = 300 m$^3$/h; $c_{active\ carbon/\ active\ sludge} = 12.5$ g/l

active sludge was lowered, thus lowering its specific surface area, while using identical concentrations of organic substances in the experiment. Purification efficacy reached 97% in the first case (Fig. 5), where concentration of active carbon in the active sludge was 12.5 g/l and its specific surface area 750 thous. m$^2$ with the concentration of etilacetate entering the equipment being 50 mg/m$^3$. In the second and third cases (Fig. 6, Fig. 7), where concentration of active carbon in the active sludge was only 5 g/l (300 thous. m$^2$) and 2.5 g/l (150 thous. m$^2$), respectively, with identical concentration of etilacetate, purification efficacy was as low as 92% in the second case and 91% in the third case.

A decrease in purification efficacy was also observed while cleaning the air polluted with butilacetate and toluene in identical conditions. More efficient purification was observed when

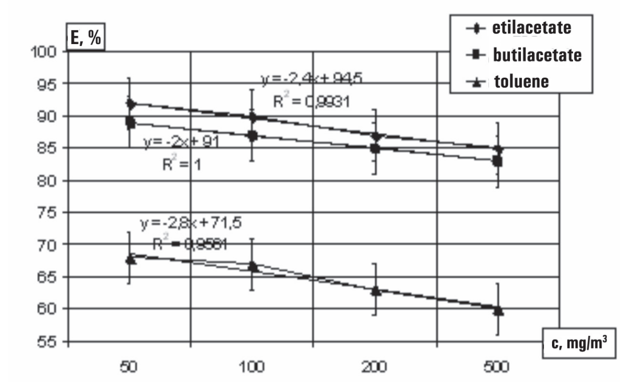


**Fig. 6.** Dependence of purification efficacy on the concentration of organic substances entering the equipment: $C_{active\ sludge} = 4$ g/l; pH = 6.9; amount of purified air = 300 m$^3$/h; $c_{active\ carbon/\ active\ sludge} = 5$ g/l

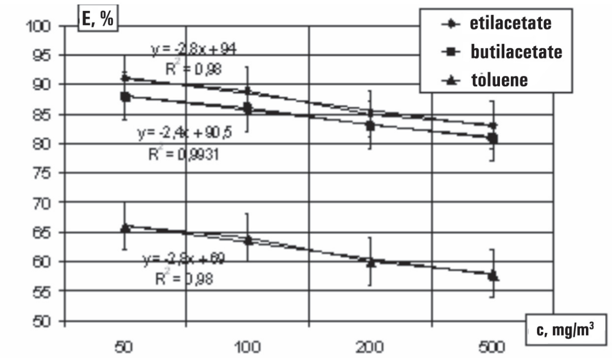


**Fig. 7.** Dependence of purification efficacy on the concentration of organic substances entering the equipment: $C_{\text{active sludge}} = 4$ g/l; pH = 6.9; amount of purified air = 300 $m^3$/h; $c_{\text{active carbon/ active sludge}} = 2.5$ g/l

concentration of organic compounds entering the equipment (etilacetate, butilacetate and toluene) was about 50 mg/$m^3$, and active carbon specific surface area was 750 thous. $m^2$.

Fig. 8 illustrates the dependence of purification efficacy on organic concentration of etilacetate entering the equipment. Purification efficacy reached 92–97% in the first case (1), where active carbon was used as a charge with active sludge in the biological air-purification equipment ($C_{\text{active sludge}}$ =4 g/l; pH = 6.9; amount of purified air = 300 $m^3$/h; $c_{\text{active carbon/ active sludge}} =$ 12.5 g/l).

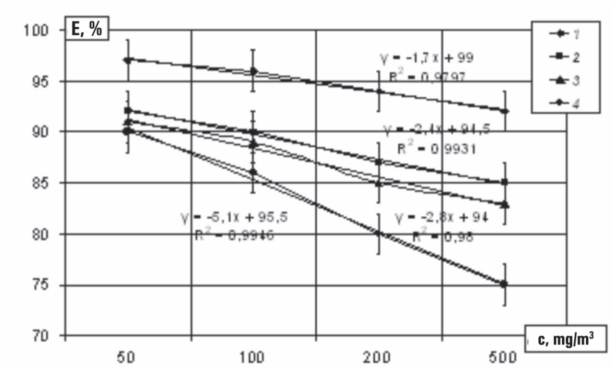


**Fig. 8.** Dependence of purification efficacy on the concentration of etilacetate entering the equipment ($C_{\text{active sludge}} = 4$ g/l; pH = 6.9; amount of purified air = 300 $m^3$/h): 1 – $c_{\text{active carbon/ active sludge}} = 12.5$ g/l; 2 – $c_{\text{active carbon/ active sludge}} = 5$ g/l; 3 – $c_{\text{active carbon/ active sludge}} = 2.5$ g/l

After the active carbon concentration in the active sludge was lowered to 5 g/l, thus decreasing its specific surface area from 750 thous. $m^2$ to 300 thous. $m^2$, purification efficacy decreased by 5–7%, when compared to the first case.

In the third case (3), the mass of active carbon used was decreased by 10 g/l more in comparison to the first case. Thus, specific surface area was decreased to 150 thous. $m^2$. The purification efficacy achieved in this case was 83–91% (it is by 6–9% lower than in the first case and by 1–2% lower compared with the second one). In the fourth case (4) polluted air was cleaned by active sludge charge only. The purification efficacy was the lowest in this case as compared to the first three cases: it decreased by 2–8% when compared to the third case, by 2–10% in comparison with the second case, and by 7–17% compared to the first case.

Figures 9 and 10 illustrate the dependence of purification efficacy on concentrations of organic substances – butilacetate and toluene – entering the equipment. The efficacy of butilacetate purification was lower in comparison with that of etilacetate under identical conditions, while toluene was shown to hardly dissolve in the suspension of activated sludge.

When cleaning the air polluted with butilacetate in the first case (1) purification efficacy achieved was 90–95%, in the second case (2) 83–89% (6–7% lower than in the first case), in the third case (3) 81–88% (7–9% lower than in the first case and 1–3% lower than in the second case). In the fourth case (4), where polluted air was cleaned by an active sludge charge only, purification efficiency achieved was only 55–75%, being 20–35% lower when compared to the first case and 13–26% lower in comparison with the third case.

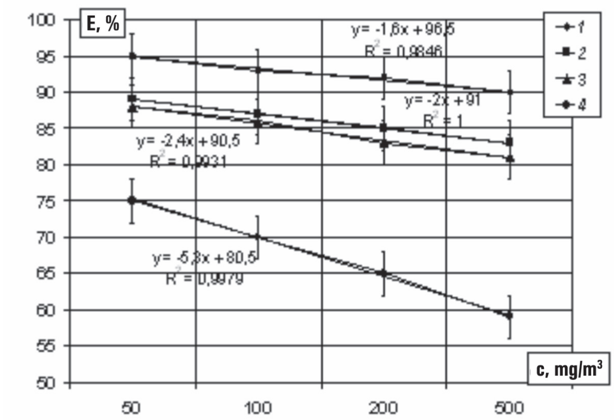


**Fig. 9.** Dependence of purification efficacy on the concentration of butilacetate entering the equipment ($C_{\text{active sludge}} = 4$ g/l; pH = 6.9; amount of purified air = 300 $m^3$/h): 1 – $c_{\text{active carbon/ active sludge}} = 12.5$ g/l; 2 – $c_{\text{active carbon/ active sludge}} = 5$g/l; 3 – $c_{\text{active carbon/ active sludge}} = 2.5$ g/l

The efficacy of purification of organic substances depends on their ability to dissolve in water. Etilacetate is easily degraded by biological means, that is why its purification efficacy is very high and markedly exceeds that of the hardly degraded toluene. The highest efficacy of toluene purification – 75% – was observed in the first case (1) (Fig. 10), where polluted air was cleaned with the suspension of active sludge and active carbon, using 12.5 g/l concentration of active carbon. The highest efficacy of toluene purification observed was by 22% lower than the highest efficacy of etilacetate and by 20% lower than that of butilacetate.

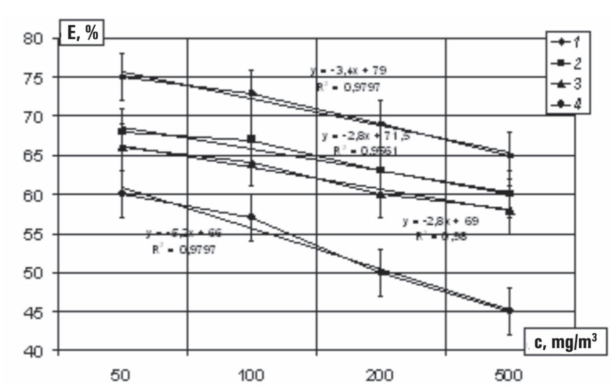


**Fig 10.** Dependence of purification efficacy on the concentration of toluene entering the equipment ($C_{\text{active sludge}} = 4$ g/l; pH = 6.9; amount of purified air = 300 $m^3$/h): 1 – $c_{\text{active carbon/ active sludge}}$ = 12.5 g/l; 2 – $c_{\text{active carbon/ active sludge}}$ = 5g/l; 3 – $c_{\text{active carbon/ active sludge}}$ = 2.5 g/l

The results of the experiments show a marked dependence of the efficacy of biological air-purification equipment on the total specific surface area of the system used. The air-purification efficacy was the highest in the first case, as the polluted air was cleaned using the suspension of active carbon and active sludge, with 12.5 g/l concentration of active carbon, and a total specific surface area for the systems was a high as 766 thous. $m^2$. The result was 450 thous. $m^2$ lower than in the second case(2), 600 thous. $m^2$ lower than in the third case (3) and 750 thous. $m^2$ lower than in the fourth (4) case, where polluted air was cleaned by active sludge charge only.

## CONCLUSIONS

1. Experiments with organic substances in the biological air-purification equipment show that equipment's efficacy depends on the mass of organic substances (concentration), as well as on concentration of active sludge and concentration of active carbon in the active sludge.

2. Experiments performed in the biological air-purification equipment with active sludge charge show that the highest purification efficacy of the equipment (99% for etilacetate, 83% for butilacetate, and 65% for toluene) is observed when concentrations of organic substances entering the equipment are around 50 mg/$m^2$, with concentration of active sludge being 9 g/l.

3. The highest purification efficacy of the equipment (99% for etilacetate, 95% for butilacetate, and 75% for toluene) were observed, when polluted air was cleaned with a suspension of active sludge and active carbon. These results are influenced by the adsorption properties of active carbon.

4. The efficacy of biological air-purification equipment depends on the specific surface area of the system used. The increase of active carbon concentration in the active sludge increases its specific surface area, thus enlarging the total active surface area of the system.

5. The highest purification efficacy of the equipment was observed for etilacetate (99%). Such a high efficacy is influenced by the high ability of etilacetate to dissolve in water making it one of organic compounds that are easily degraded by biological degradation. The highest purification efficacy observed while using butilacetate was 95%. This value measured 75% for toluene, as it is hard to degrade by biological means.

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### References

1. Bakas A., Baltrėnas P., Jakštaitė A. 2001. *Biologinis oro valymo įrenginys*. LR patentas Nr. 4798.
2. Baltrėnas P., Paliulis D. 2002. *Absorbciniai oro valymo filtrai*. Monografija. Vilnius: Technika. 219 p.
3. Baltrėnas P., Vaiškūnaitė R. 2003. *Microbiological investigation of activated pine – bark charge for biofilters*. Vilnius: Technika. Vol. XI. Nr. 3. P. 29–35.
4. Baltrėnas P., Zigmontienė A. 2003. Simulating volatile organic substance absorption in the aqueous phase of activated mud. *Chemical and Petroleum Engineering*. Kluwer Academic. Vol. 39. No. 5–6. P. 362–365.
5. Jakštaitė A., Bakas A., Šimaitis R. 1999. Biologinis oro valymas aktyviuoju dumblu. *Aplinkos inžinerija*. Vilnius: Technika. Vol. VII. No. 3. P. 118–123.
6. Janssen D. B., Oldehuis R., Van den Wijngaard A. J. 1989. Degradation of xenobiotic compounds by microorganisms. *Tagungsbericht der VDI-Kommission Reinhaltung der Luft. Biologische Abgasreinigung*. VDI-Verlag. P. 25–41.
7. Zigmontienė A., Bakas A., Šimaitis R. 2002. Organinių junginių sorbavimas biologinio oro valymo įrenginyje vykstant aktyviojo dumblo recirkuliacijai. *Aplinkos inžinerija*. Vilnius: Technika. Vol. X. No. 2. P. 89–92.
8. Zigmontienė A., Bakienė L. 2003. Investigation of volatile organic compound absorbtion in water. *Journal of Environmental Engineering and Landscape Management*. Vol. XI. No. 2. P. 75–79.
9. Kirtys S., Dabrilaitė G. 2002. $Al_2O_3$ – aktyvintų anglių adsorbento sintezės ir savitojo paviršiaus tyrimai. *Cheminė technologija*. Kaunas. Vol. XI. No. 5(26) P. 26–30.
10. Zigmontienė A., Baltrėnas P. 2004. Biological purification of air polluted with volatile organic compounds by using active sludge recirculation. *Journal of Environmental Enginering and Landscape Management*. Vol. XII. No. 2. P. 45–52.

**Aušra Zigmontienė**

### BIOLOGINIO ORO VALYMO METODAS TAIKANT VEIKLIOJO DUMBLO IR AKTYVINTOS ANGLIES SUSPENSIJĄ

*Santrauka*

Vieni svarbiausių nūdienos klausimų daugelyje pasaulio šalių – tai racionalus gamtinių išteklių naudojimas bei aplinkos apsauga nuo įvairios kilmės teršalų, kurie kenksmingi ne tik aplinkai, bet ir žmogui. Vis dažniau kalbama apie įvairias žmonių sveikatos ir aplinkos apsaugos problemas, kurias sukelia nekontroliuojami į aplinką išskiriamų lakiųjų organinių teršalų (LOJ) kiekiai. Šiai problemai spręsti vienas perspektyviausių metodų – biologinis oro valymas.

Orui, užterštam lakiaisiais organiniais junginiais, valyti taikomi biologinio oro valymo įrenginiai su veikliojo dumblo įkrova. Nepaisant jų nedidelių matmenų, ant įkrovos užaugusiais mikroorganizmais valoma daug, iki 100 tūkst. $m^3$/h, užteršto oro. Efektyvesniam valymui ir desorbcijos proceso eliminavimui patogu biologiniame oro valymo įrenginyje naudoti veikliojo dumblo ir aktyvintos anglies suspensiją.

Aktyvinta anglis pasižymi geromis adsorbcinėmis savybėmis, todėl suderinama biologiniame oro valymo įrenginyje su veikliuoju dumblu.

Tyrimų tikslas – padidinti lakiųjų organinių junginių, esančių ore, išvalymo efektyvumą, taikant veikliojo dumblo ir aktyvintos anglies suspensiją. Eksperimentai atlikti su trimis skirtingomis organinėmis medžiagomis – etilacetatu, butilacetatu ir toluenu. Tyrimai atlikti keičiant organines medžiagas, jų koncentracijas ir aktyvintos anglies koncentraciją veikliajame dumble.

**Raktažodžiai**: lakieji organiniai junginiai, biologinis oro valymas, veiklusis dumblas, aktyvinta anglis, adsorbcija