2012 / 26

Combination of Straw and Ceramic Materials for Biofiltration of Volatile Hydrocarbons

Andrejs Berzins[1], Katrina Potapova[2], Silvija Strikauska[3], Olga Muter[4], [1-4]*University of Latvia*

Abstract. **The performance of five biofiltration columns (total volume 1.58 L each) packed with rape straw and ceramic beads in different composition was compared. Columns with packing material were treated by (i) addition of medium and inoculum of hydrocarbon-degrading bacteria consortium MDK-EKO-7; (ii) addition of medium; (iii) addition of water; (iv) feeding by diesel vapours. The highest removal efficiency for volatile hydrocarbons among biofiltration columns tested, i.e., 46.7 %, was found to be in the column containing rape stalks. The most intensive compaction of packing material was detected in the columns with ceramic beads and rape pods, i.e., 8.7 and 10.6 %, respectively, probably due to the synergistic effect of the mixture of organic and inorganic material. Compaction in other columns varied in the range of 3.3 ÷ 4.0 %. The same columns were characterized by the most considerable decrease of cellulose in the rape pods after 44 days experiment. Activity and concentration of microorganisms in the columns were estimated by FDA hydrolysis microbial activity and plate count. The results of this study indicate to the significance of the composition of packing material.**

Keywords: **volatile hydrocarbons; biofiltration; rape straw; ceramic beads.**

Introduction

The emission of volatile hydrocarbons from petroleum-contaminated sites may contribute to regional air quality problems. Biological methods involving biofilter has been shown to be promising alternative compared to the traditional technologies for the control of many gaseous pollutants [1, 2]. Since the packing material is the main factor influencing both reactor long-term operational stability and costs, a packing material should ideally be durable and cheap to assure a robust and economical performance. Additionally, it should contain the nutrients required for microbial metabolism [3, 4, 5]. Specific surface area, porosity, density, water retention capacity and the nutrients availability are some of the most important characteristics of the filter media [6].

Organic materials are suitable to release extra nutrients and able to keep water content at optimal levels for microorganisms and show the highest specific surface [4]. Organic bedding material is expected to have a higher absorptivity when compared to inorganic material. Soccol et al. [7] reported that microbial adsorption for wood chips and inorganic silica is 248 mg/g and 2 mg/g, respectively.

On the contrary, inorganic or synthetic materials offers higher contact surface and produce cleaner drainage water. Otherwise, pressure drop have been determined for each packing materials as function of flow rate, water content and bed porosity [4].

Among the natural carriers reported, compost, peat, soil and the wood derivatives are the most extensively used while perlite, glass beads, ceramic rings, polyurethane foam, etc. are some of the several synthetic or inert carriers which have been studied [4, 8]. Wood charcoal was found to be an effective biofilter media for toluene biodegradation [9]. The biofilter bed packed with 35% fibrous peat, 35% sallow peat, 10% barley straw, composts from sewage plant and horse manure - 10% each exhibited up to 89 % of ammonia biofiltration efficiency [10].

Biofiltration of toluene in the column packed with wood chips and propylene spheres was tested by [11]. Decrease in toluene removal efficiency and increase in pressure drops of the filter bed were simultaneously observed during the operation period due to excess biomass accumulation, mostly in the inlet section [11].

Comparative study on biofiltration of “binary” gas mixtures was reported earlier. For example, biofiltration effect of a composite-ceramic carrier made of 1 : 1 mixture of diatomic and bentonite clay showed a relatively high maximum removal capacity of H_2S and toluene vapour [12]. A gas mixture containing ammonia and six VOCs was fed to the reactors packed with a new hybrid (inert/organic) packing material that consists of spherical argyle pellets covered with compost [3].

A wheat straw biofilter made for dairy wastewater treatment, demonstrated a decrease microbial activity at low temperatures of operation and high oil and grease concentration, that reduced nutrient transfer to the biofilm [13].

Biomass is a critical factor in gas biofiltration, and uneven distribution and excess accumulation within gas biofilters often result in operational problems such as clogging, excessive head loss, and channel formation of gas streams within biofilter beds, which leads to deterioration in performance [14]. A well established biofilter is a complex and structured ecosystem. Microbial communities are sensitive to variations in environmental conditions in gas phase biofilters [15]. A complex bacterial succession occurred in the reactor in response to the increasing concentrations of the pollutant [16].

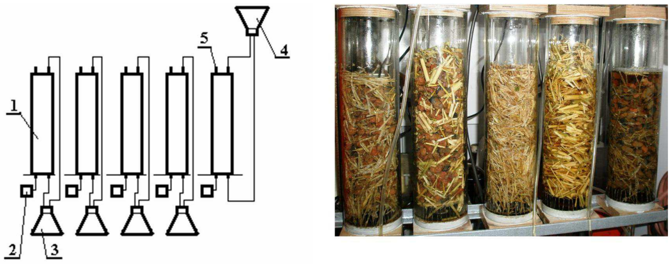
Biological treatment begins with the treatment of contaminants from the air phase to the water phase. The efficiency of this process primarily depends on the kinetics of micro processes such as absorption, adsorption, diffusion and biodegradation [5, 17, 18].

In this study, evaluation of a laboratory scale biofilter packed with ceramic beads and/or rape straw for the treatment of diesel vapours was done. Growth and activity of bacteria consortium in biofiltration columns, removal efficiency for volatile hydrocarbons, as well as compaction and degradation of organic carrier in dependence on the composition of packing material and treatment mode was examined.

MATERIALS AND METHODS

The “5 columns” model system

The model system consisted of 5 biofiltration columns was established. The height and inner diameter of glass columns are 330 mm and 78 mm, respectively (Fig.1). Columns were packed with ceramic beads and rape straw. Before the experiment, rape (*Brassica napus* L.) straw was divided into two parts, i.e. pods and stalks, and used for column packing separately. The rape straw was divided in two parts because the pods and stalks have different mechanical structure. Operating conditions are summarized in Table 1. Ceramic beads prepared under laboratory conditions, were kindly provided by Dr.R.Svinka (RTU).



A B

Fig. 1. The „5 columns” model system used in the experiment. A – the scheme of the system (1 – the column with packing material; 2 - air compressor; 3 - collector for circulated liquid, 4- inlet for circulation liquid, 5 – air outlet); B – biofiltration columns filled with packing material.

Microorganisms and growth conditions

A consortium of bacteria MDK-EKO-7 consisted of 5 strains of *Stenotrophomonas maltophilia* and 2 strains of *Pseudomonas* spp. It had been previously isolated from hydrocarbon-contaminated soils and had exhibited the ability to degrade hydrocarbons.

The inoculum with concentration 7.1 x 10^8 cfu/mL was prepared by 24 h cultivation in the liquid medium at 28 °C under aerobic conditions with agitation 140 rpm. The medium composition was as follows, g/L: Na_2HPO_4 x $12H_2O$ – 6.0; KH_2PO_4 – 3.0; NaCl – 0.5; molasses – 5.0; yeast extract – 2.0.

Cell concentration was expressed as colony-forming units (CFU) per ml and determined by making serial decimal dilutions and plating on Tryptone Glucose Yeast Extract Agar (TGA) (Sifin, Germany). CFU were counted after 72 h plate incubation at 28 °C.

Biodegradation experiment

For biodegradation experiment, commercially available diesel oil was used. The concentration of volatile petroleum hydrocarbons (VPH) was measured using Dräger tubes™ 10/a 8101691, for petroleum hydrocarbons. Preliminary experiment showed that the concentration of volatile petroleum hydrocarbons (VPH) generated from 10 g diesel at air flow 520 mL/min, - is time dependent. The VPH concentration under tested conditions in the time interval from 6 to 9 min was found to be constant, i.e. 150 ppm. A mean air flow rate was maintained in each column using air pumps (AC-1500, Resun, China). Flasks containing 10 g diesel were prepared separately for each column and each experimental flux set. Addition of liquid medium with inoculum of bacteria consortium MDK-EKO-7, as well as sterile water was performed according to the scheme shown in Table 1.

TABLE 1.

THE SCHEME OF THE EXPERIMENT WITH THE “5 COLUMNS” MODEL SYSTEM

Operation day No.	Treatment*	Period of treatment, h
1	Water (distilled, sterile)	24
2	Medium with inoculum	48
9	Medium	24
14	Medium	48
22	Medium	24
29	Water (distilled, sterile)	1
31	Water (distilled, sterile)	1
37	Water (distilled, sterile)	1
44	Water (distilled, sterile)	1

* Volume of liquid added to each column was 1 L.

Analytical methods

Auto Kjeldahl Unit K-370 (BÜCHI Labortechnik AG, Germany) was used to determine total nitrogen content according to ISO 5983-2:2005. To measure total carbon, the carbon, sulphur analyzer ELTRA CS 530 (GmbH, Germany) was used. Potassium and phosphorous was measured according to LVS EN ISO 6869: 2002 and ISO 6491: 1998, respectively. The concentration of N-NH_4^+ was determined colorimetrically with Nessler’s reagent. Redox potential and pH value was measured with a Hanna pH213 pH-meter (Hanna Instruments, USA). To determine enzymatic activity, hydrolysis of fluoresceine diacetate (FDA; Fluka, Switzerland), after a 1h incubation at +37°C was determined [19]. Concentration of hemicellulose and cellulose was calculated after NDF (LVS EN ISO 16472: 2006) and ADF (LVS EN ISO 13906: 2008) determination. Lignin was determined according to LVS EN ISO 13906: 2008). Ash was determined according to ISO 5984: 2002/Cor.1: 2005.

RESULTS AND DISCUSSION

Growth and activity of bacteria consortium in biofiltration columns in dependence on the composition of packing material and treatment mode

Formation of biofilm onto the carrier surface was performed by inoculation of bacteria consortium MDK-EKO-7 followed by 4 incubation in medium. As was shown in our previous experiments, the growth of consortium can be influenced by the presence of ceramic beads or organic carrier (results not shown). As the most important criteria for evaluating microbial activity in the columns, the number of aerobic heterotrophic microorganisms and FDA hydrolysis activity in culture liquid was tested.

After the first cycle of 48h cultivation (Day 2), the number of CFU in culture liquid, which was discharched from the columns, was similar for all 5 columns and varied in the range of (5.3 ÷ 8.4) x 10^8 cfu/mL. Additional testing was done with rape straw without inoculum, thus evaluating the growth of microorganisms of non-sterile straw. The number of heterotrophs in culture liquid after 48h cultivation of pods and stalks was $7.2x10^7$ and $1.1x10^6$, respectively.

Enzymatic activity of microorganisms in culture liquid differed among columns tested. The highest FDA hydrolysis activity after the first cycle of 48h cultivation (Day 2) was detected in the column No.4 with rape stalks, i.e., 21.5 mg FDA/L h. The lowest activity – in the column No.5 with ceramic beads and rape pods, i.e., 9.9 mg FDA/L h, respectively (Fig.2). The following incubation cycles, either in medium or water, - resulted in considerably lower enzymatic activity, as compared to the first cycle (Day 2).

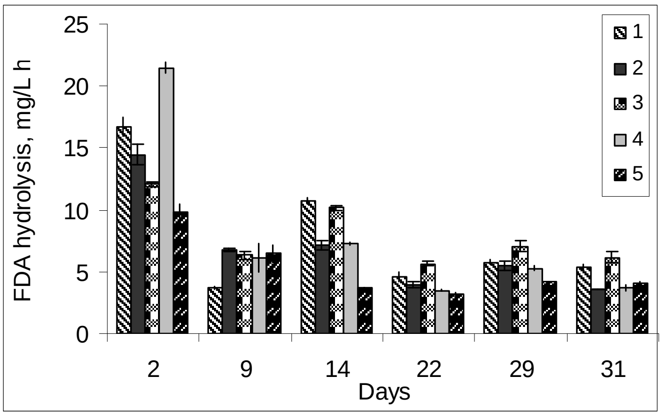


Fig.2. FDA hydrolysis activity of bacteria consortium MDK.EKO-7 in liquid phase discharged from the column after treatment. Treatment mode corresponded to the experimental day - is indicated in Table 1. Error bars represent the standard deviation at 5% level of significance.

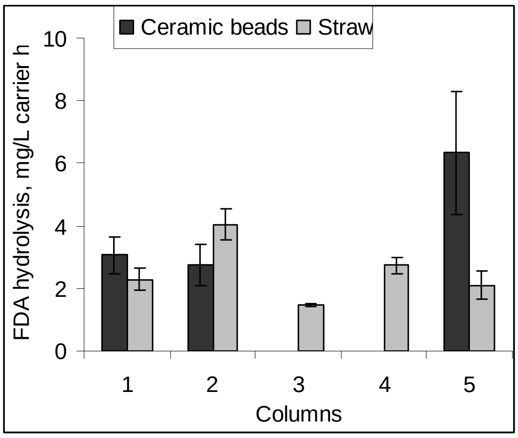


Fig.3. FDA hydrolysis activity of bacteria consortium MDK.EKO-7 attached onto carrier after 44 days experiment. Treatment mode corresponded to the experimental day - is indicated in Table 1. Data on FDA hydrolysis activity of the carrier per volume were calculated, taking in consideration the ratio weight : volume of native straw. Error bars represent the standard deviation at 5% level of significance.

At the end of the experiment, comparative study of the FDA hydrolysis activity onto carrier was performed. As shown in Fig.2 and 3, an average microbial enzymatic activity per 1 L onto carrier and in culture liquid was similar. An exception was only the first cycle of 48h cultivation (Day 2), which resulted in notably higher FDA hydrolysis activity in liquid phase (Fig.2).

Interestingly, that some products of rape straw degradation are known to pose inhibition effect to microorganisms. Rape tissues, like those of most other cruciferous plants, are known to contain glucosinolates. In intact rape cells, these glucosinolates are located in vacuoles. Disruption of the tissues during degradation leads to release of the glucosinolates that are hydrolyzed by the enzyme myrosinase, leading to the liberation of thiocyanates, isothiocyanates, and nitriles. These compounds are known to have inhibitory or lethal effects on soil bacteria and fungi [20, 21, 22]. As shown in Figure 3, a slight inhibitory effect was found for the column No.3 packed with rape pods.

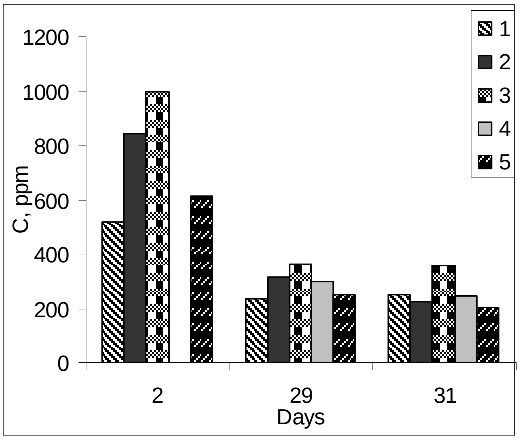
Physico-chemical changes of organic packing material during experiment

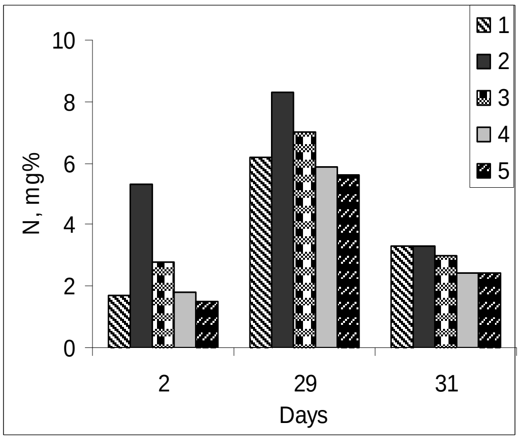
The pH value and redox potential of culture liquid was similar among columns in each cycle. At the same time, in the frames of each cycle, which corresponds to the specific treatment mode, - the pH value and redox potential were different. For example, the pH value after the 1st cycle with water (Day 1) varied from 5.7 to 6.2, while after the cycle with medium and inoculum – from 6.6 to 7.1. The following treatment with medium did not influence the pH and redox potential of liquid phase. Redox potential gradually decreased during experiment from 40 mV to -40 mV. According to [23], biodegradation of straw is followed by the changes of pH. In particular, irrespective of the initial pH of the medium, a decrease of the pH value to 6.0, and a further slow increase to 8.0-9.0 until cellulose was degraded completely, was found during rice straw aerobic degradation. Differences in the dynamics of pH values in different processes can be explained by their specific conditions.

The results of this experiment indicate that addition of medium and water to packing material, as well as microbial growth, - influenced the model biofiltration system as a whole and carrier condition, in particular. As far as the packing material of the columns contained organic biodegradable carrier, the balance of the main biogenic compounds in the biofiltration system should be controlled. The lowest C/N ratio in straw can serve as a criterion to expect its faster mineralization [22, 24]. According to [22], the wheat, rape, and alfalfa residues presented different C/N ratios, with 94, 51, and 27, respectively. Our testing results showed the C/N ratio for average sample of rape straw was 100. In absolute units (%), the ratio C:N:P:K in the rape straw used in this study, was found to be 48.6:0.48:0.13:1.44, respectively. Additionally, neutral detergent fibre and acid detergent fibre concentration were determined and were 70.9 % and 58.3 % dw, respectively.

The data on the concentration of carbon, nitrogen and sulphur in liquid phase after the Day 2, 29 and 31 are summarized in Figure 3. The highest amount of carbon and sulphur leached from the column, was found to be after the packing material was contacted with medium (Fig. 4A,C). In turn, the highest leaching of nitrogen was detected at Day 29, after the rinsing of packing material with water (Fig.4B).

The concentration of biogenic compounds in leachate is originated from the both, cultivation medium and straw degradation products. Straw degradation can be estimated by the changes in the concentrations of cellulose, hemicellulose and lignin. The fiber structure of straw consists of cellulose microfibrils, bound to each other with hemicellulose and lignin. The hemicellulose content consists of branched and acetylated carbohydrates. The lignin content of the straw consists of polymerized molecules with a phenolic structure. As reported by [25], the rape straw consisted of 32 % cellulose, 16 % hemicellulose, 18 % lignin.





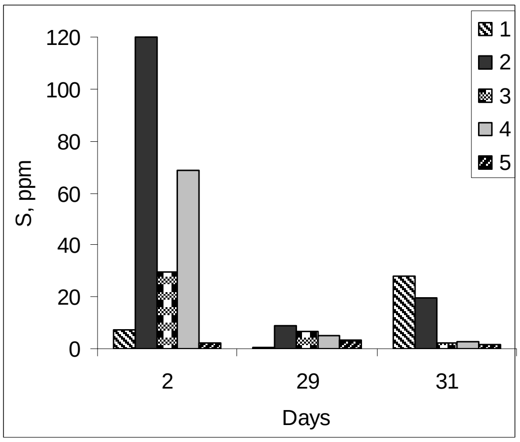


Fig.4. Leaching of carbon (A), nitrogen (B) and sulphur (C) from the packing organic material in dependence on the treatment mode. Treatment mode corresponded to the experimental day - is indicated in Table 1.

The remaining solid phase after wet oxidation process became enriched in cellulose and contained 54 % cellulose, 14 % hemicellulose, 23 % lignin, 3 % ash [25]. Our results showed that the rape straw before packing consisted of 47 % cellulose, 13 % hemicellulose, 11 % lignin (Table 2). After 44 days experiment, the concentration of these compounds differed in dependence on the packing composition used in the column. The most considerable decrease of cellulose was detected in the columns with rape pods (Columns No.1, 3, and 5). The concentration of hemicellulose and lignin were increased in all columns tested (Table 2).

TABLE 2.

CHEMICAL CHARACTERISTICS OF RAPE STRAW USED AS AN ORGANIC PACKING MATERIAL IN THE EXPERIMENT

Items or parameters	Before packing	After 44 days experiment, columns				
		1	2	3	4	5
Dry weight, %	97.09	28.76	16.90	18.03	14.76	14.07
Total nitrogen, % (dw)	0.48	0.40	0.16	0.16	0.22	0.35
N/NH_4^+, g/kg	0	0.30	0	0	0	0.30
Hemicellulose, % (dw)	12.56	15.63	19.50	18.15	17.75	17.26
Cellulose, % (dw)	47.43	26.16	46.18	36.48	46.43	30.34
Lignin, % (dw)	10.78	20.36	19.16	15.62	17.01	21.21

Removal of volatile hydrocarbons in biofiltration columns

For evaluating an effectiveness of five tested columns, the following characteristics were compared: (i) packing material saturation capacity time; (ii) removal efficiency for volatile hydrocarbons, as well as (iii) compaction of the packing material during 44 days experiment.

It was shown that inoculation and cultivation of bacteria consortium led to an increase of the saturation capacity time in the columns with combined packing materials, i.e. ceramic beads and pods or stalks (columns No.1, 2 and 5). At the same time, the columns packed with organic material only (columns No.3 and 4), demonstrated a rather high saturation capacity time for volatile hydrocarbons already at the beginning of the experiment (Table 3).

The highest removal efficiency for volatile hydrocarbons among biofiltration columns tested, i.e., 46.7 %, was found to be in the column No.4, which was packed with rape stalks (Table 3). Repeated measurement of the concentration of volatile hydrocarbons after 1 h showed a drastic decrease of the removal efficiency for all five columns. However, the column No.4 demonstrated the best results among tested sets (Table 3). A decrease of biofiltration efficiency after 1 h of hydrocarbons loading indicate to the limiting effect of the columns size and the rate of air flow, and, therefore, - the concentration of volatile hydrocarbons.

The rate of air flow, as well as other physical characteristics of the packing material, - are dependent on the conditions of organic carrier, its degradation capacity and compaction. The most intensive compaction of packing material was detected in the columns No.1 and 5, filled with ceramic beads and rape pods, i.e. 8.7 and 10.6 %, respectively. Compaction in other columns varied in the range of 3.3 ÷ 4.0 % (Table 3).

TABLE 3.

OPERATING CONDITIONS OF THE "5 COLUMNS" MODEL SYSTEM

Items or parameters	Columns				
	1	2	3	4	5
Packing material	Ceramic beads / rape pods	Ceramic beads / rape stalks	Rape pods	Rape stalks	Ceramic beads / rape pods
Layer weight, g (ceramic beads / straw)	345.24 / 15.00	345.22 / 40.08	30.08	80.03	318.35 / 15.02
Layer height, mm	180	235	210	250	175
Layer volume, L	0.882	1.152	1.029	1.225	0.858
Temperature, °C	16-19	16-19	16-19	16-19	16-19
Inlet hydrocarbon concentration, ppm	150	150	150	150	150
Air flow direction	Upflow	Upflow	Upflow	Upflow	Upflow
Air flow rate, m^3/h	0.0312 ÷ 0.0378	0.0360 ÷ 0.0438	0.0276 ÷ 0.0426	0.0414 ÷0.0480	0.0198 ÷ 0.0264
Removal efficiency for volatile hydrocarbons, % (Day 9 / Day 9, repeated measurement after 1h / Day 29)	26.7 / 6.7 / 26.7	33.3 / 20.0 / 33.3	33.3 / 13.3 / 26.7	46.7 / 33.3 / 40.0	20.0 / 13.1 / 20.0
Packing material saturation capacity time for volatile hydrocarbons, s (Empty, Day 1 / Inoculated, Day 2 / Incubated, Day 14)	111 / 150 / 130	152 / 283 / 15	289 / 268 / 297	320 / 291 / 109	240 / 324 / 250
Compaction of the packing material after 44 days experiment, % of the total column height	8.7 (73.9-65.2)	4.0 (84.4-80.4)	3.3 (74.4-71.1)	3.6 (90.0-86.4)	10.6 (72.5-61.9)

CONCLUSIONS

The results obtained in this study allow to make the following conclusions:

1. Different composition of packing material in five tested columns did not result in significant differences of culture growth. After the first cycle of 48h cultivation (Day 2), the number of CFU in culture liquid, which was discharched from the columns, was similar for all 5 columns and varied in the range of (5.3 ÷ 8.4) x 10^8 cfu/mL.
2. At the end of the experiment, an average FDA hydrolysis activity per 1 L onto carrier and in culture liquid was similar. An exception was only the first cycle of 48h cultivation (Day 2), which resulted in notably higher FDA hydrolysis activity in liquid phase.
3. Inoculation and cultivation of bacteria consortium led to an increase of the saturation capacity time in the columns with combined packing materials, i.e., ceramic beads and pods or stalks (columns No.1, 2 and 5). At the same time, the columns packed with organic material only (columns No.3 and 4), demonstrated a rather high saturation capacity time for volatile hydrocarbons already at the beginning of the experiment.
4. The highest removal efficiency for volatile hydrocarbons among biofiltration columns tested, i.e., 46.7 %, was found to be in the column No.4, which was packed with rape stalks. A decrease of biofiltration efficiency after 1 h of hydrocarbons loading indicate to the limiting effect of the columns size and the rate of air flow, and, therefore, - the concentration of volatile hydrocarbons
5. The most intensive compaction of packing material was detected in the columns No.1 and 5, filled with ceramic beads and rape pods, i.e., 8.7 and 10.6 %, respectively. Compaction in other columns varied in the range of 3.3 ÷ 4.0 %. The most considerable decrease of cellulose was detected in the columns with rape pods.

ACKNOWLEDGEMENTS

This study was supported by the State Research program Nr. 2010.10-4/VPP-5 NatRes, the 1st Project „Mineral Resources", projects 1.1. and 1.6., as well as the project 09.1177 financed by Latvia Council of Sciences. Authors are grateful to Dr.sc.ing. R.Svinka and Dr.habil.sc.ing. V.Svinka from RTU for providing ceramic beads.

REFERENCES

1. Rene, E.R., Murthy, D.V.S., Swaminathan, T. Performance evaluation of a compost biofilter treating toluene vapours. *Process Biochemistry*, 2005, vol. 40, p. 2771-2779.
2. Álvarez-Hornos, F. J., Gabaldón, C., Martinez-Soria, V., Marzal, P., Penya-Roja, J.M. Performance of peat biofilters treating ethyl acetate and toluene mixtures under non-steady-state conditions. ***In:*** *Biotechniques for Air Pollution Control*. Eds. C.Kennes, M.C.Veiga. Universidade da Coruňa, Servizo de Publicacións, A Coruňa, 2007, p. 367-377.
3. Hernández, J., Prado, Ó.J., Almarcha, M., Lafuente, J., Gabriel, D. Development and application of a hybrid inert/organic packing material for the biofiltration of composting off-gases mimics. *Journal of Hazardous Materials*, 2010, vol. 178, p. 665–672.
4. Dorado, A.D., Gamisans, X., Gabriel, D., Lafuente, J. A comparative study of the characteristics and physical behaviour of different packing materials commonly used in biofiltration. ***In:*** *Biotechniques for Air Pollution Control.* Eds. C.Kennes, M.C.Veiga. Universidade da Coruňa, Servizo de Publicacións, A Coruňa, 2007, p. 561-572.
5. Devinny, J.S., Deshusses, M.A., Webster, T.S. Biofiltration for air pollution control. *Lewis Publisher*, Boca Raton, Florida, 1999, 300 p.
6. Janni, K.A., Maier, W.J., Kuehn, T.H., Yang, C.-H., Bridges, B.B., Velsey, D., Nellis, M.A. Evaluation of biofiltration of air-An innovative air pollution control technology. *ASHRAE Transactions*, 2001, vol. 107, p. 198-214.
7. Soccol, C.R., Woiciechowski, A.L., Vandenberghe, L.P.S., Soares, M., Neto, G.K., Thomaz-Soccol, V. Biofiltration: an emerging technology. *Indian Journal of Biotechnology*, 2003, vol. 2, p. 396-410.
8. Kennes, C., Veiga, M.C. Bioreactors for waste gas treatment. *Kluwer academic publishers*, Dordrecht, The Netherlands, 2001.
9. Singh, K., Singh, R.S., Rai, B.N., Upadhyay, S.N. Biofiltration of toluene using wood charcoal as the biofilter media. *Bioresource Technology*, 2010, vol. 101, p. 3947–3951.
10. Tymczyna, L., Chmielowiec-Korzeniowska, A., Saba, L. Biological Treatment of Laying House Air with Open Biofilter Use. *Polish Journal*

of Environmental Studies, 2004, vol. 13, N 4, p. 425-428.

11. Xi , J., Hu, H.-Y., Qian, Y. Effect of operating conditions on long-term performance of a biofilter treating gaseous toluene: Biomass accumulation and stable-run time estimation. *Biochemical Engineering Journal*, 2006, vol. 31, p.165–172.
12. Park, O.H., Han, J.E. Performance of composite-ceramic and organic-clay carriers in biofilters treating hydrogen sufide gas and toluene vapour. *Korean Journal of Chemical Engineering*, 2007, vol. 24, N 2, p. 233-238.
13. Shah, S.B., Bhumbla, D.K., Basden, T.J., Lawrence, L.D. Cool temperature performance of a wheat straw biofilter for treating dairy wastewater. *Journal of Environmental Science and Health, Part B: Pesticides, Food Contaminants, and Agricultural Wastes*, 2002, vol. 37, N 5, p. 493-505.
14. Yang, C.P., Suidan, M.T., Zhu, X.Q., Kim, B.J. Biomass accumulation patterns for removing volatile organic compounds in rotating drum biofilters. *Water Science and Technology*, 2003, vol. 48, p. 89–96.
15. Yang, C., Chen, H., Zeng, G., Yu, G., Luo, S. Biomass accumulation and control strategies in gas biofiltration. *Biotechnology Advances*, 2010, vol. 28, p. 531–540.
16. Borin, S., Marzorati, M., Brusetti, L., Zilli, M., Cherif, H., Hassen, A., Converti, A., Sorlini, C., Daffonchio, D. Microbial succession in a compost-packed biofilter treating benzene-contaminated air. *Biodegradation*, 2006, DOI 10.1007/s10532-005-7565-5.
17. Rene, E.R., Swaminathan, T. Co-treatment of benzene and toluene vapours in a biofilter: A factorial design approach. ***In:*** *Biotechniques for Air Pollution Control*. Eds. C.Kennes, M.C.Veiga. Universidade da Coruňa, Servizo de Publicacións, A Coruňa, 2007, p. 133-142.
18. Baquerizo, G., Maestre, J.P., Sakuma, T., Deshusses, M.A., Gamisans, X., Gabriel, D., Lafuente, J. A detailed-model of a biofilter for ammonia removal: model parameters analysis and model validation. *Chemical Engineering Journal*, 2005, vol. 113, p. 205–214.
19. Chen, W., Hoitink, H.A.J., Schmitthenner, A.F., Tuovinen, O.H. The role of microbial activity in suppression of damping-off caused by *Pythium ultimum*. *Phytopathology*, 1988, vol. 78, N 3, p. 314-322.
20. Sarwar, M., Kirkegaard, J.A., Wong, P.T.W., Desmarchelier, J.M. Biofumigation potential of brassicas—III. In vitro toxicity of isothiocyanates to soil-borne fungal pathogens. *Plant and Soil*, 1998, vol. 201, p. 103–112.
21. Charron, C.S., Sams, C.E. Inhibition of Pythium ultimum and Rhizoctonia solani by shredded leaves of Brassica species. *Journal of the American Society for Horticultural Science*, 1999, vol. 124, p. 462–467.
22. Pascault, N., Cecillon, L., Mathieu, O., Henault, C., Sarr, A., Leveque, J., Farcy, P., Ranjard, L., Maron, P.-A. In Situ Dynamics of Microbial Communities during Decomposition of Wheat, Rape, and Alfalfa Residues. *Microbial Ecology*, 2010, vol. 60, p. 816-828.
23. Liu, J.B., Wang, W.D., Yang, H.Y., Wang, X.F., Gao, L.J., Cui, Z.J. Process of rice straw degradation and dynamic trend of pH by the microbial community MC1. *Journal of Environmental Sciences*, 2006, vol. 18, N 6, p. 1142-6.
24. Trinsoutrot, I., Recous, S., Bentz, B., Lineres, M., Cheneby, D., Nicolardot, B. Biochemical quality of crop residues and carbon and nitrogen mineralization kinetics under nonlimiting nitrogen conditions. *Soil Science Society of America Journal*, 2000, vol. 64, p.918–926.
25. Thygesen, A., Vahlgren, L., Frederiksen, J.H., Linnane, W., Thomsen, M.H. SSF Fermentation of Rape Straw and the Effects of Inhibitory Stress on Yeast. Bioethanol, Prof. Marco Aurelio Pinheiro Lima (Ed.), 2012, ISBN: 978-953-51-0008-9, DOI: 10.5772/24445

Andrejs Berzins, Mag. ing., researcher. Field of research – design of bioreactors, mixing intensty studies, studies on solid state and submerged fermentation technologies.
Institute of Microbiology & Biotechnology, University of Latvia
Adress: 4 Kronvalda blvd., Riga LV-1010, Latvia
E-mail: andrejs54@inbox.lv

Katrina Potapova, Mag.biol., received bachelor's and master’s degrees in environmental sciences from the University of Latvia (Faculty of Biology). Field of research – microbiology, biotechnology.
Institute of Microbiology & Biotechnology, University of Latvia
Adress: 4 Kronvalda blvd., Riga LV-1010, Latvia
E-mail: kgp19@inbox.lv

Silvija Strikauska, Dr. biol., senior researcher. Field of research – agro-technology, biotechnology.
Institute of Microbiology & Biotechnology, University of Latvia
Adress: 4 Kronvalda blvd., Riga LV-1010, Latvia
E-mail: silvija.strikauska@llu.lv
Latvia University of Agriculture
Adress: Liela Str., Jelgava LV-3001, Latvia

Olga Muter, Dr. biol., senior researcher. Research interests: soil microbiology, eco-toxicology, environmental biotechnologies.
Institute of Microbiology & Biotechnology, University of Latvia
Adress: 4 Kronvalda blvd., Riga LV-1010, Latvia
E-mail: olga.mutere@lu.lv

Andrejs Bērziņš, Katrīna Potapova, Silvija Strikauska, Olga Muter. Salmu un keramikas materiālu kombinācija gaistošo ogļūdeņražu biofiltrācijai

Rakstā salīdzinātas piecas biofiltrācijas kolonnas (katras kopējais tilpums 1,58 litri), kas dažādās attiecībās pildītas ar rapša salmiem un keramikas granulām. Lai nodrošinātu bioplēves veidošanos uz nesējmateriāliem, kolonnām ar pildmateriālu periodiski (I) pievienoja barotni un ogļūdeņražu sadalošu baktēriju konsorciju MDK-EKO-7; (II) pievienoja barotni; (III) pievienoja ūdeni; kā arī (IV) kolonnās ievadīja dīzeļdegvielas tvaikus. Mikroorganismu aktivitātes un kultūras šķidruma īpašību novērtēšanai noteica tajā fluoreceīna diacetāta (FDA) hidrolīzes aktivitāti, heterotrofo mikroorganismu koloniju veidojošo vienību (KVV) skaitu, pH un redoks potenciālu, kā arī slāpekļa, oglekļa un sēra koncentrāciju. Pēc 48 stundu baktēriju kultivācijas, KVV skaits kultūras šķidrumā bija līdzīgs visās piecās kolonnās un variēja robežās (5,3 ÷ 8,4) x 10^8 kvv/mL. Mikroorganismu FDA hidrolīzes aktivitāte kultūras šķidrumā kolonnās pēc kultivēšanas pirmajā ciklā atšķīrās. Augstākā FDA hidrolīzes aktivitāte bija ceturtajā kolonnā ar rapša stublājiem, t.i., 21,46 mg FDA/L nesēja stundā. Nākamajos inkubācijas ciklos barotnē vai sterilā destilētā ūdenī enzimātiskā aktivitāte bija ievērojami zemākā nekā pēc pirmā cikla. Starp pārbaudītajām kolonnām vislielākā efektivitāte attīrīšanai no gaistošiem ogļūdeņražiem (46,7%) bija kolonnai ar rapša stublāju pildījumu. Vislielāko pildmateriāla blīvēšanos novēroja kolonnās ar keramikas granulām un rapša pākstīm, attiecīgi 8,7 un 10,6 %. Pārējās kolonnās materiāla blīvēšanās bija robežās no 3,3 līdz 4,0 %. Tām pašām kolonnām bija raksturīga vislielākā celulozes satura samazināšanās rapša pākstīs pēc 44 dienu eksperimenta. Rezultāti pierādīja, ka kopējais slāpeklis rapša salmos visos variantos samazinās, salīdzinot ar kontroles variantu. Tas varētu būt saistīts ar daļēju tā izskalošanu no kolonnām, kā arī ar tā izmantošanu mikroorganismu aktivitātes rezultātā. Pētījuma rezultāti norāda uz biofiltra pildmateriāla sastāva svarīgumu. Tālākie pētījumi jāveic lielākos aparātos.

Андрейс Берзиньш, Катрина Потапова, Силвия Стрикауска, Ольга Мутер. Комбинация соломы и керамического материала для биофильтрации летучих углеводородов

Сравнили эффективность пяти биофильтрационных колонн (общий объем для каждой 1,58 л), наполненных разными сочетаниями соломы рапса и керамических гранул. Для формирования биоплёнки на поверхности носителей, колонны с упаковочным материалом периодически обрабатывали, (I) добавляя питательную среду и консорциум бактерий МДК-ЕКО-7, способный деградировать углеводороды; (II) добавляя питательную среду; (III) добавляя воду; а также (IV) подавали летучую фракцию дизельного топлива. Показателями активности микроорганизмов и свойств культуральной жидкости являлись гидролиз флуоресцеина диацетата (ФДА), число колонии образующих единиц (КОЕ) гетеротрофных бактерий, pH и редокс потенциал, а также концентрация азота, углерода и

серы. После 48 часового культивирования бактерий, число КОЕ во всех пяти колоннах было схожим и варииpовало в пределах (5,3 ÷ 8,4) x 10^8 КОЕ/мл. В то же время, активность гидролиза ФДА различалась: наиболее высокая активность отмечена в 4-ой колонне, наполненной стеблями рапса, которая составила 21,46 мг ФДА/л носителя в час. В последующих циклах инкубации в питательной среде или стерильной дистиллированной воде, активность гидролиза ФДА была значительно ниже, по сравнению с первым циклом. Среди тестируемых вариантов, наиболее высокая эффективность удаления летучих углеводородов (46,7%) была в колонне, содержащей стебли рапса. Наиболее интенсивное уплотнение наполнителя было обнаруженно в колоннах с керамическими гранулами и стручками рапса, т.е., 8,7 и 10,6%, соответственно. В других колоннах уплотнение было в диапазоне 3,3 ÷ 4,0%. Эти же колонны характеризовались наиболее значительным снижением целлюлозы в стручках рапса после 44 дней эксперимента. Концентрация общего азота в соломе рапса к концу эксперимента снизилась во всех вариантах, что может быть обусловлено его частичным вымыванием из колонн, а также использованием микроорганизмами в процессе их жизнедеятельности. Результаты этого исследования указывают на важное значение состава упаковочного материала. Дальнейшие эксперименты должны быть выполнены в колоннах большего размера.