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POSSIBILITIES OF USING COMPOST AS OIL DERIVATIVES SORBENT IN SIMULATED CONDITIONS

MOŻLIWOŚCI ZASTOSOWANIA KOMPOSTU JAKO SORBENTU ROPOPOCHODNYCH W WARUNKACH SYMULOWANYCH

Abstract: Mineral oil products show a multisided negative impact not only on the environment but also to human beings. Oil products leaks are the result of traffic accidents and work done while handling fuels and lubricants. One method of limiting the spread of these substances is using sorbents. From a practical point of view the absorption rate of the sorbent is important, because it significantly determines the degree to limit their environmental impact. The tests of the ability to absorb gasoline and diesel were carried out on the reference surface - the glass and the actual surface - asphalt (asphalt specimen was taken from the so-called wearing course of a roadway lane). The rate of absorption was estimated on the basis of the test images that were automatically taken at intervals of 5 seconds. The study was conducted for commercial sorbents and compost from municipal waste. The study was conducted for the air-dry material and the humidity of 20, 30 and 40%. The best results were obtained with compost from mixed waste, and the worst for commercial organic sorbent. There were also no apparent effects of high humidity on the absorption rate of petroleum products. Thus, increased to 20% moisture of sorbent does not disqualify it from using it in practice. Only 40% moisture content lead to high decrease of sorption properties. On the basis of the research it was found that compost from municipal waste can be used to replace expensive commercial sorbents currently used both in professional rescue operations and in household use.

Keywords: compost, petroleum substances, sorption

Liquid fuels produced in the process of refining crude oil have become the basis for road transport - both truck and passenger. Daily consumption of oil in the world is estimated at about 10 million tones Mg. In Poland, liquid fuels sale is growing and according to Polish Organisation of Oil Industry and Trade in 2020 it will amount to 30 million cubic meters. Fuel production, its distribution, and in particular reloading generate threat of uncontrolled entry into the soil and ground water [1]. A threat of fuels and lubricants leak into the environment is also a problem that occurs while land traffic accidents (about 34.4 thow. in 2013), especially if a leak regards tank trucks carrying significant quantities of gasoline or other fuels. Production and utilization of sorbents for the removal of these impurities generate high costs, resulting in a constant search for substitutes for these materials.

The ever increasing quantity of urban waste forces society to seek new possibilities and new technologies for transforming wastes into reusable material. Composts made from municipal waste are real sources of biomass, however they often contain many harmful or toxic compounds [2]. However, using compost waste as a sorbent has many advantages. Compost is a natural product, which is manufactured microbiologically from mixed municipal solid waste stream or from segregated biodegradable fraction of municipal waste.

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What is more it is also biologically active product which supports the process of decomposition absorbed oil derivatives [3-5]. Its stability allows long-term storage and quick transport to any place by road or rail [6]. An additional advantage of this material is also its low price. It is important to launch a new cheap and environmental friendly sorbents which could be use in each place also by non high qualified personnel or people in private properties. It is especially chance for low-quality composts made of mixed MSW or biodegradable MSW with high content of impurities as glass, metal or plastics particles.

Material and methods

For the purpose of the research, the following materials were chosen: compost from mixed municipal waste created by technology MUT - Dano (marked "D") and compost from segregated biodegradable fraction of municipal waste created by MUT - Herhof technology (marked "H"). Both tested municipal solid waste (MSW) composts had typical properties for products obtained in accordance with the above mentioned types of materials and technologies [7]. For comparison purposes, commercial sorbents were also tested: organic (marked "O") and mineral (marked "M"). Basic parameters of investigated materials were analyzed by electrometric methods (pH and EC), and FES (Ca, K) after mineralization with aqua regia. Organic matter, TOC, N, P were analyzed with methodology according to Polish Standards.

Dynamic of sorption experiments were carried out on the reference surface - glass (sodium type) and the actual surface - asphalt (asphalt specimen was taken from the so-called wearing course) slanted at an angle of 5%. The tested sorbent was spread with a 3 mm thick layer on a surface (glass or asphalt) and then lead-free petrol (CAS: 86290-81-5, with density 742 g/dm^3) or diesel oil (CAS: 68334-30-5, with density 818 g/dm^3) was dispensed by burette on the upper edge of the layer. The quantity of dispensed organic liquid in each case was 50 cm^3. The rate of absorption was estimated on the basis of pictures taken automatically at intervals of 5 seconds. The study was conducted for the air-dry sorbents. For comparison purposes, the total sorption capacity of the tested dry materials was set and it was based on the difference in the weight of 10 g sorbent in a vessel after contact with the organic phase (gasoline or diesel). The experiments were carried out at 20°C.

Results and discussion

Basic characteristic of sorbents used in experiments is shown in Table 1. Both composts can be connect to organo-mineral materials, with high content of water soluble mineral compounds. High content of salts could be a phytotoxicological problem in case of use investigated composts as fertilizer or material for soil quality improve. Additionally a lot of composts produced from municipal solid waste (MSW) can contain a great number of impurities *eg* metal and glass particles, textiles or plastics. So, it is necessary to find other possibility of use low-quality composts. These materials contain both mineral and organic fraction and have different granulometric composition (Table 2) [8]. Especially high content of fine fraction (< 0.1 mm) was found in organic sorbent. Also compost D has characteristic composition with almost 35% content over 4 mm. Granulometric composition suggest that sorbent O with the fine particles could have the best sorption properties,

however composts D and H with high organic matter content also could be suitable for organic liquids sorption. Different particles size in sorbent is an advantage because road surface has a lot of small holes and clefts, so it is important to fill up all hollows with sorbent.

Table 1

Main characteristic of sorbents used in experiments (n = 5)

Parameter	H	D	M	O
Organic matter [% d.w.]	34.4±1.47	42.2±3.38	0.86±0.02	98.8±0.10
TOC [% d.w.]	21.4±6.2	24.9±4.1	< 0.5	95.7±0.28
pH_{H2O}	7.74-7.92	7.89-8.12	6.22-6.28	3.76-3.78
EC [mS/cm]	4.16±0.10	3.05±0.41	0.69±0.12	0.09±0.02
N [% d.w.]	1.24±0.3	0.93±0.6	< 0.2	< 0.5
P_2O_5 [% d.w.]	0.75±0.2	0.82±0.3	< 0.3	0.42±0.1
K_2O [% d.w.]	2.15±0.6	3.65±0.8	7.9±1.2	1.2±0.2
CaO [% d.w.]	6.74±1.1	12.8±2.4	21.4±2.9	< 1.0

Table 2

Granulometric composition of investigated sorbents

Grain size [mm]	H	D	M	O
> 4	27.4	34.8	0.4	0.0
> 2	11.8	12.5	15.0	43.6
> 1	18.6	20.0	10.6	54.7
> 0.5	11.9	13.9	17.2	1.70
> 0.25	19.7	16.9	22.7	0.07
> 0.1	8.2	5.2	20.0	0.01
< 0.1	2.4	1.5	9.16	0.01

Commercial mineral sorbent M which is in common use in rescue actions in Poland. Pure mineral factory product contains low amount of organic carbon, nitrogen and phosphorus compounds. This material is time-stable easy to long-term store and use. It is suitable also for all common chemicals except hydrofluoric acid. After use it has to be stored on special landfill for hazardous wastes. Organic sorbent O contains low amount of nitrogen and phosphorus compounds. Moreover sorbent O made of peat has low amount of calcium and low pH value. After use it has to be burn in incineration plant or stored on landfill for hazardous wastes. Moreover, this material should be removed from hydrocarbons sorption purposes due to low global resources of peat.

Table 3

Total sorption capacity of dry tested materials at 20°C (n = 3) [g/kg d.w.]

	H	D	M	O
ES95	407 ±20	629 ±30	529 ±6.0	4638 ±138
ON	532 ±29	747 ±55	617 ±11	4224 ±117

The amount of absorbed substances over time is one of the most important parameters that indicate the effectiveness of the sorbent. The sooner petroleum substances is absorbed, the less likely it is to get into the environment. Thus, the sorbent which is being used should

have the highest possible kinetic absorption of petroleum substances. From a practical point of view, sorption capacity is also essential because it determines the total amount of sorbent that must be used in order to eliminate a certain amount of oil derivatives. Table 3 shows the results of total sorption capacity of tested sorbents in room temperature.

In the case of compost and widely used by the emergency services mineral sorbent the results are similar, for both gasoline and diesel. However, organic sorbent absorbs gasoline in an amount of 7 to 11 times larger, and diesel fuel from 5.5 to almost 8 times higher as compared to other sorbents tested. These amounts are lower than the sorption capacity of hydrophobic fibers of the kapok tree (*Ceiba pentandra*) however kapok fibers after use should be incinerated what lead to increase of rescue action costs [9]. Figure 1 shows the results of the absorption capacity of gasoline ES95 by the sorbents and carried out within 50 seconds.

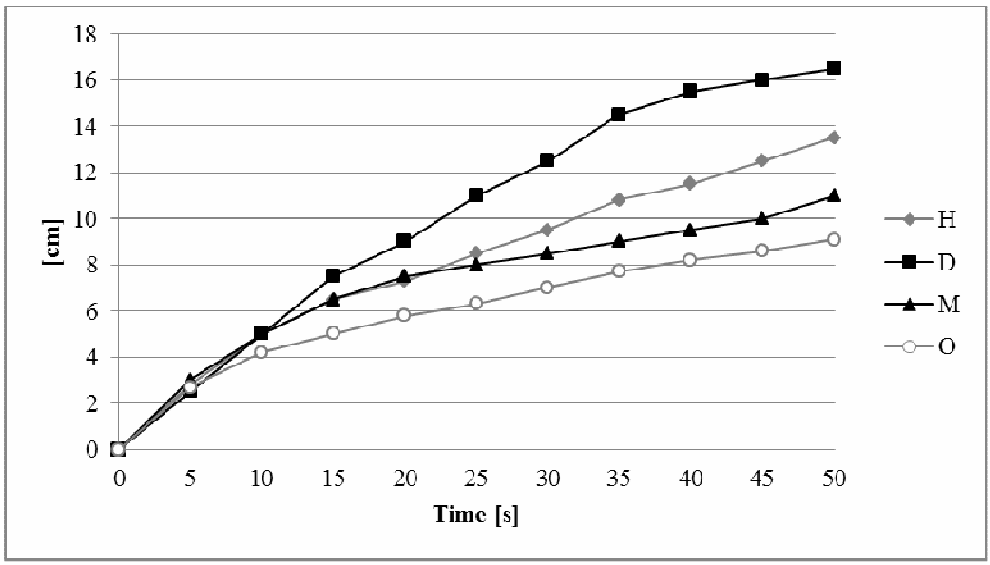

Fig. 1. Gasoline absorption possibilities by investigated sorbents in air-dry state (glass surface with slope 5%)

After the first 10 seconds of the contact between petrol and sorbents, the lowest growth rate was characterized by a sorbent O. In the 15th second of the contact of solid and liquid phase, the highest amount of gasoline ES95 absorbed was for sorbent D and the lowest for material O. In the 50th second of the test in the case of sorbents H and D 16.5 and 13.5 cm bed length was saturated. Surprisingly, the weakest result (9.1 cm) was recorded for the sorbent A. This material was originally expected to have much higher absorption rate, but because of its granulometric composition - a significant share of fine fraction - the achieved result was unsatisfactory. Figure 2 shows the results of the same test carried out on diesel.

The achieved results were worse than in the case of gasoline. This is due to the higher oil density (0.818 g/cm^3) than gasoline used in the experiment (0.742 g/cm^3). The best result (14 cm was achieved as in the case of gasoline for the sorbent D, and the worst (6.1 cm) similarly to previously reported result for the sorbent O. This may be due to the

phenomenon of swelling the peat fibers, and thus sealing the sorbent bed what impedes the migration of organic liquid to a new bed. Sorbent H showed worse sorption capacity than gasoline - the absorption rate was only 8.3 cm/50 seconds and is worse than the one obtained by the sorbent M (10.5 cm).

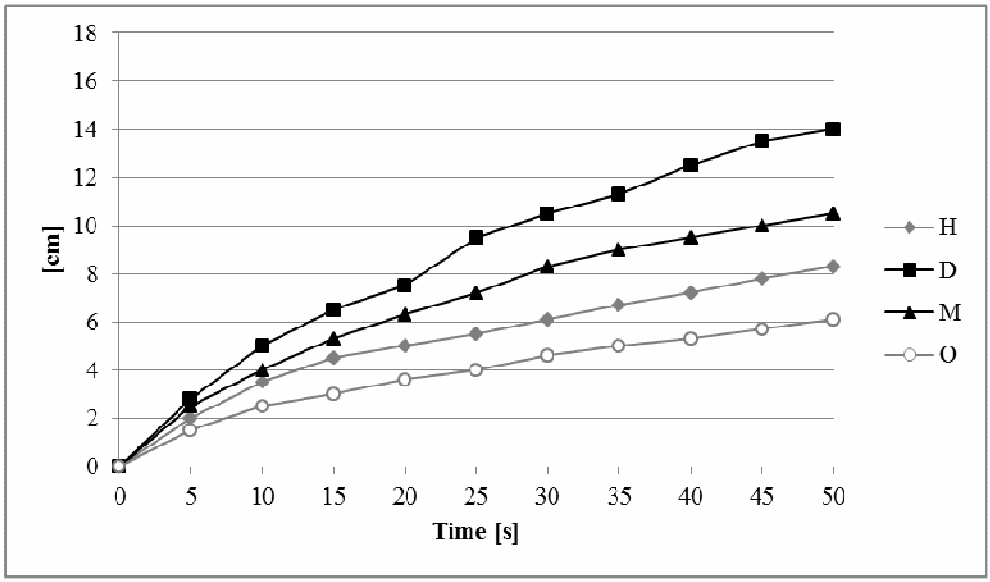

Fig. 2. Diesel oil absorption possibilities by investigated sorbents in air-dry state (glass surface with slope 5%)

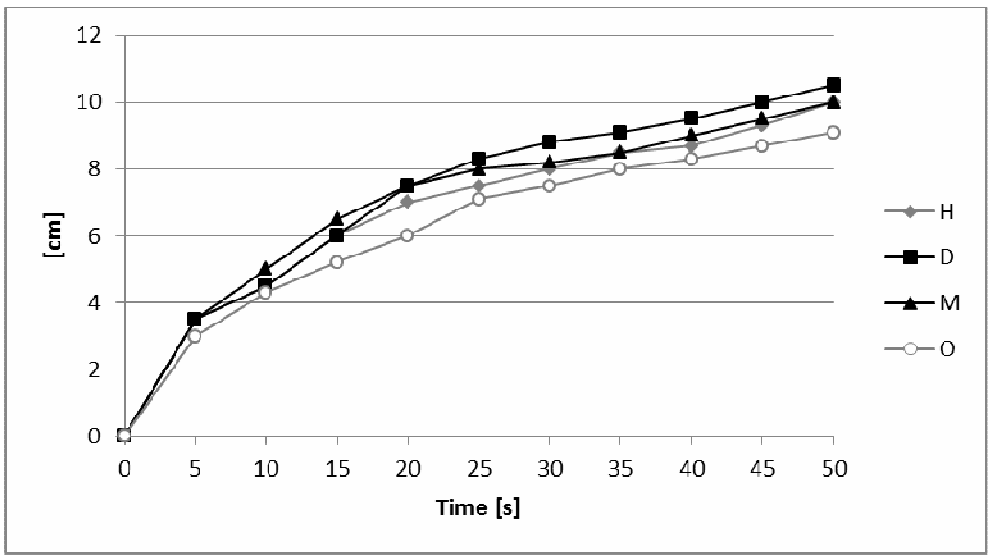

Fig. 3. Gasoline absorption possibilities by investigated sorbents in air-dry state (asphalt surface with slope 5%)

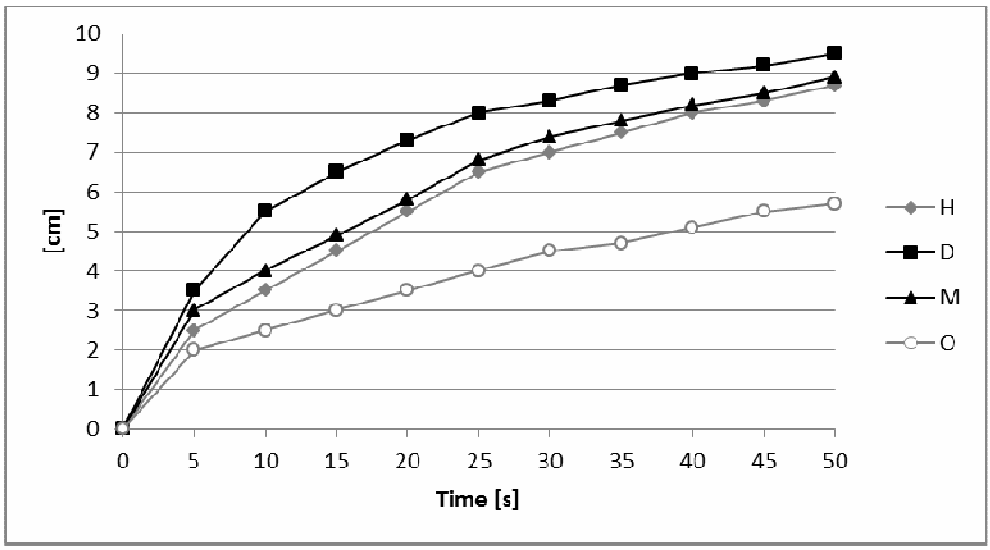

Fig. 4. Diesel oil absorption possibilities by investigated sorbents in air-dry state (asphalt surface with slope 5%)

In the tests carried out on the asphalt surface (Figs. 3 and 4), the obtained results demonstrate similar characteristics of absorption rate comparing the sorbents with each other. However, both in the case of gasoline and oil, on the asphalt surface the observed results were worse. It is probably due to a notable surface roughness, where in the slots the tested liquid may be collected before it will be absorbed by the sorbent. Moreover, both tested liquids as petroleum derivatives (like asphalt) have a far greater capacity of wetting asphalt compared to the glass surface. For both tested liquids (gasoline and diesel) after removal of the used up sorbent, surface contamination was observed for both glass and asphalt, which was the lowest for sorbent O, what resulted from a significant proportion of small organic fraction. Similar results in sorption capacity have been achieved carrying out the sorption by the capillary rise, but absorbed amount of oil was 3-4 times lower than the total sorption capacity specified here [8]. Mature composts have relatively high amount of water. It could be a disadvantage in use these materials as sorbents. Obtained results from pretests (Table 4), show that only high amount of water (40%) could lead to lower sorption properties. Especially commercial sorbent O had a good sorption capacity in all tested moisture levels. Poor results were obtained for sorbents M and H. Increase of water content lead rapidly drop of sorption capacity to level 3-4 times lower than in total dry state. This phenomenon was also observed in case of sorbent D, but sorption capacity was lower only two times. After that all further experiments were performed for tested sorbents with a water content of 20% (m/m). In the case of the reference surface (glass) the increase in water content in the tested materials did not affect negatively on the rate of absorption of petrol and diesel by commercial sorbents M, O and H. Sorbent absorption rate reduction was observed only for the sorbent D which was moistened with petrol at the length of 16.5 and 11 cm respectively for dry and wet material. In the case of diesel oil wetting, these values are 14 and 8.4 cm. The decrease of absorption rate was significant (respectively

33 and 40%), but recorded only in this case. Experiments carried out on the asphalt surface showed no negative effects of 20% water content in the absorbent material on wetting rate of the organic liquid. Probably the best sorption results observed in case of compost D is a result of high content of glass and metal impurities. This mineral particles lead go better contact of sorbed substance and solid organic matter contain in sorbent. It also reason of poor results achieved in case of sorbent O, where great amount of fine needle-like parts have a lot of very small There were an experiments made with other organic sorbents like coconut husk, rice husk, wood chips, kapok fiber, cattail fiber for oil removal from water stream [10]. Obtained results were good (comparable with polyester fiber) only in case of cattail fiber. However cattail is a wild plant which should be collected usually in wetland areas and dried before use. An additional disadvantage of this material is also its conflict with avifauna lifecycle - a lot of birds use cattail fields as reproduction areas. In case of high price of commercial sorbents, MSW composts appear as a real alternative in common use. Easy to made materials as composts have high stability allows long-term storage and this is cheap to transport them to any place. An additional advantage of this materials is high number of multi-microorganisms consortium which could effective accelerate petroleum products degradation process. In this case compost should be stored in wet state what can negatively lead on hydrocarbons sorption process as mentioned above. It is also possible to additional accelerate of decomposition hydrocarbons sorbed with MSW composts by using special enzyme preparations but in final effect total price of rescue action will be higher [11]. Compost is common material in each garden, so it could be use daily for sorption of oil products which leaking from old cars engines in garages or private park sites. Container with wet compost placed under oil leak point could appear as low-cost simple solution for catching and effective decomposing all drops of engine oil. It is especially interesting for truck and building machines park sites where engine and hydraulic oils leaks are very common.

Table 4

Total sorption capacity of tested sorbents in various moisture content for trade petroleum products

Moisture [%]	ES95				ON			
	H	D	M	O	H	D	M	O
0	407	629	529	4638	532	747	617	4224
20	345	596	274	4410	474	731	369	3870
30	226	556	190	4070	322	632	308	3600
40	105	328	116	3780	141	381	193	3550

Conclusions

In case of accidental oil leaks it is very important to quick and effective remove petroleum products from road surface to avoid soil or surface water contamination. The results demonstrate excellent absorption dynamics of petroleum liquid by compost sorbents. The highest absorption dynamics was recorded in the case of compost from mixed waste. This is probably the result of a high proportion of organic matter. The lowest dynamics (with the highest sorption capacity) was observed in the case of commercial sorbent O, which may be due to the seal of capillary between the sorbent particles on the way of swelling peat fibers, and as a result causing the migration of oil products in a direction

parallel to the face of the sorbent bed. However, commercial sorbent O had the highest sorption capacity it is made of peat, so use of this sorbents type should be minimized due to global peat resources.

Moistness of tested sorbents did not affect negatively both the dynamics of the and the total length of the sorbent layer that is moistened by the tested liquid within 50 seconds. Thus, increased to 20 % moistness of the sorbent does not disqualify it from using it in practice. Due to keep rescue action cheap, it is very important to use compost without additional operations like sieving, drying or cleaning from impurities.

Obtained results show that compost could be an effective sorbent also for wide sorption purposes also in private garages and industrial areas.

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References

[1] Chang JI, Lin Ch, Ch. A study of storage tank accidents. J Loss Preven in the Process Indust. 2006;19:51-59. DOI: 10.1016/j.jlp.2005.05.015.

[2] Rosik-Dulewska C, Ciesielczuk T. The possibilities of using waste compost to remove aromatic hydrocarbons from a solution. Environ Eng. London: CRC Press Taylor&Francis Group; 2010;237-242.

[3] Gestel van K, Mergaert J, Swings J, Coosemans J, Ryckeboer J. Bioremediation of diesel-oil contaminated soil by composting with biowaste. Environ Pollut. 2003;125:361-368. DOI: 10.1016/S0269-7491(03)00109-X.

[4] Franco I, Contin M, Bragato G, De Nobili M. Microbiological resilience of soils contaminated with crude oil. Geoderma. 2004;121:17-30. DOI: 10.1016/j.geoderma.2003.10.002.

[5] Tsui L, Roy WR. The potential application of using compost charts for removing the hydrophobic herbicide atrazine from solution. Bioresour Technol. 2008;99:5673-5678. DOI: 10.1016/j.biortech.2007.10.026.

[6] Tognetti C, Mazzarino MJ, Laos F. Improving the quality of municipal organic waste compost. Bioresour Technol. 2007;98:1067-1076. DOI: 10.1016/j.biortech.2006.04.025.

[7] Poluszyńska J, Siemiątkowski G, Paciorkowski M. Charakterystik von Komposten aus Abfallen - im Licht der geltenden Vorschriften. Scientific Works of Institute of Ceramics and Building Materials. 2012;10:191-210. http://icimb.pl/opole/wydawnictwa/prace-icimb/327.

[8] Ciesielczuk T, Rosik-Dulewska C, Lenartowicz J. Investigations of composts as a potential sorbents of aliphatic hydrocarbons. Proc ECOpole. 2013;7(1):43-48. DOI: 10.2429/proc.2013.7(1)005.

[9] Wang J, Zheng Y, Wang A. Coated kapok fiber for removal of spilled oil. Mar Pollut Bull. 2013;69:91-96. DOI: 10.1016/j.marpolbul.2013.01.007.

[10] Khan E, Virojnagud W, Ratpukdi T. Use of biomass sorbents for oil removal from gas station runoff. Chemosphere. 2004;57:681-689. DOI: 10.1016/j.chemosphere.2004.06.028.

[11] Ciesielczuk T, Krzyśko-Łupicka T. Degradation of *n*-alkanes in oil polluted soil after stimulation by fyre-zyme enzyme preparation and hydrogen peroxide. Ecol Chem Eng A. 2013;20(4-5):525-533. DOI: 10.2428/ecea.2013.20(04)049.

MOŻLIWOŚCI ZASTOSOWANIA KOMPOSTU JAKO SORBENTU ROPOPOCHODNYCH W WARUNKACH SYMULOWANYCH

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Abstrakt: Produkty przerobu ropy naftowej wykazują wielokierunkowe negatywne oddziaływanie nie tylko na środowisko, ale także na człowieka. W wyniku katastrof w ruchu lądowym lub prac związanych z przeładunkiem paliw i smarów dochodzi do wylewów produktów naftowych. Jedną z metod ograniczających rozprzestrzenianie się tych substancji jest zastosowanie sorbentów. Z praktycznego punktu widzenia istotna jest szybkość pochłaniania substancji ropopochodnych przez sorbent, co w znaczący sposób determinuje stopień ograniczenia ich szkodliwego oddziaływania na środowisko. Doświadczenia zdolności pochłaniania benzyny oraz oleju napędowego przeprowadzono na powierzchni wzorcowej - szklanej oraz powierzchni rzeczywistej - asfaltowej (próbkę asfaltu pobrano z tzw. warstwy ścieralnej pasa drogowego). Szybkość pochłaniania oszacowano na podstawie zdjęć testowych wykonywanych automatycznie w interwale co 5 sekund. Badania przeprowadzono dla sorbentów komercyjnych oraz kompostów z odpadów komunalnych. Badania prowadzono dla materiałów powietrznie suchych oraz o wilgotności wynoszącej 20, 30 i 40%. Najlepsze wyniki uzyskano dla kompostu z odpadów zmieszanych, a najgorsze dla komercyjnego sorbentu organicznego. Nie zanotowano także wyraźnego wpływu podwyższonej wilgotności na szybkość pochłaniania produktów naftowych. Zatem podwyższona do 20% wilgotność sorbentu nie dyskwalifikuje go z zastosowania w praktyce. Dopiero wilgotność na poziomie 40% znacznie obniża właściwości sorpcyjne badanych materiałów. Na podstawie przeprowadzonych badań stwierdzono, iż komposty z odpadów komunalnych mogą z powodzeniem zastąpić drogie sorbenty komercyjne stosowane obecnie zarówno w czasie akcji ratowniczych, jak i w warunkach domowych.

Słowa kluczowe: kompost, substancje ropopochodne, sorpcja