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ANALYSIS OF THE EFFECTIVENESS OF POLYPROPYLENE FIBERS USAGE AS SORBENTS OF OIL SPILLS RESULTING FROM THE TRANSPORT ACCIDENTS

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Abstract. The effectiveness of polypropylene fibers as sorbents of oil-water emulsions was the object of the research in the present publication. Thus the sorption capacity of the synthetic material of the regional production with for emulsions of different concentration was investigated.

Keywords: oil spills, sorbent, polypropylene fibers, emulsions, imbibition, effective thickness.

Introduction

The transport industry is considered to be the main source of the petrochemicals contamination and consequently makes significant contribution to the environment quality deterioration. The majority of spills of crude oil and its products is a result of the accidents during transportation process, petrochemicals storage and refuelling.

Absolutely all petrochemicals are reviewed as xenobiotics. They are able to cause damaging of the marine and coastal-terrestrial biota in the cases resulting from the water transport accidents. Nowadays significant deterioration of the environmental is observed by reason of oil spills incited by pipeline systems and terrestrial transport. Penetrating through the soil horizon petrochemicals can reach underground water table that makes difficultness of their control, removal and consequently, remediation.

It is important to underline that beside the irreversible ecological consequences, oil spills have always negative economical impacts mainly due to necessity to remediate damaged habitats and loss of the energy resource.

In case of oil penetration in the aqueous system, various physical and chemical processes occur, which are able to cause changes of oil characteristics over time. One of such common processes is oil dispersing in water or so-called emulsification. Correspondingly, the oil-water emulsions are considered as metastable, microheterogeneous systems consisting of two practically non intersoluble liquids (Daling, Strøm 1999; Wei *et al.* 2003).

There are different technologies of oil removal from the aquatic systems. They are subdivided mostly regarding to the utilization mechanisms on: the mechanical sorption, the dispersant application (Lessard, DeMarco 2000; Chapman *et al.* 2007) and *in situ* burning (Putorti 1994; Bitting 1999; Mullin, Champ 2003). Usage of various sorbents is considered to be preferred due to an ability to recovery of oil that diminishes risks of the environmental damages and ensures the ecologically safety. Moreover sorbents are characterized by relatively high sorption capacity and easiness of handling on contaminated areas in majority of accidents (Choi, Moreau 1993; Adebajo *et al.* 2003; Qi *et al.* 2011).

Sorbents can be classified in regard to their nature: natural sorbents (Choi, Moreau *et al.* 1993; Anthony 1994; Haussard *et al.* 2003; Saito *et al.* 2003; Eakalak *et al.* 2004; Suni *et al.* 2004; Amuda, Ibrahim 2006; Cambiella *et al.* 2006; Hussein *et al.* 2008; Qi *et al.* 2011), inorganic mineral materials (Toyoda, Inagaki; Beall 2003; Bastani *et al.* 2006; Carmody *et al.* 2007; Rajaković-Ognjanović *et al.* 2008; Karakasi, Moutsatsou 2010; Dikla Zadaka-Amir *et al.* 2013) and synthetic fibres (Wei *et al.* 2003; Rethmeier, Jonas 2003; Zhu *et al.* 2011).

This publication focuses on application of polypropylene fibres as a sorbent of the oil-water emulsions. The principal advantages of such synthetic materials are high hydrophobicity level and buoyancy, the excellent imbibition and retention capacity, simplicity of absorbed oil recovering and sufficient reusability (Wei *et al.* 2003; Rethmeier, Jonas 2003; Zhu *et al.* 2011). Generally a process of sorption depends on different factors, among which are: sorption time, obviously the type of a sorbent, various physical and chemical properties of absorbed medium. Moreover the thickness of a sorption material is also considered to be an affecting parameter.

Purpose of the work

Therefore research work was conducted to evaluate the effectiveness of the proposed polypropylene fibers as a sorbent of various emulsions. Its assessment gives an opportunity to improve remediation of the environment contaminated with the petrochemicals and deminishes risks of the negative consequences emerging in future.

There are specific cases, where the important point is supposed to be an assessment of the sorption material capability to transfer an absorbed substance in the vertical direction as a function of time. From another point of view, measurement of the height of an imbibed substance is not sufficient to make conclusions concerned effectiveness of the sorption process. Thus the subject of the work was the investigation of an effectivess of emulsions imbibition by the synthetic fibers and analysis of the dependence of such parameter as mass of absorbed substance on the time function. There were also attempts to calculate so-called effective thickness of material what can be usefull in the modelling of the observed imbibition process.

General characteristics of the materials

The main objective of the research work was the dependence between effective quantity of a substance absorbed by the polypropylene fiber and thickness of the mentioned material.

The researches were conducted at the Faculty of Process and Environmental Engineering in the Technical University of Lodz.

The polypropylene fiber "Polfilter" of regional production ("Zakład Pracy Chronionej", Lodz) with different thickness values was applied as a synthetic sorbent of the investigated substances.

The oil-based liquid employed in the sorption testing was kerosene oil „Dragon" (produced by "Zakład Chemii Budowlanej" in Kampinos, Poland) and its emulsions with various concentrations of dispersed phase.

Gelatin "Delecta" (JSC "Rieber Foods Polska") was applied to increase the viscosity of the prepared emulsions. The surfactant was „Rokacet" obtained from Chemical Plant „Rokita" (Brzeg Dolny) and served for reducing the interfacial tension between phases in emulsions.

Experimental procedures

Emulsions were prepared by means of kerosene oil mixing with water and dispersed phase concentrations were as follows: 0.5%; 1%; 5%; 10% and 20%. The concentration of surfactant was equal to 2 ml and proposed fractions of gelatine consequently were: 0.05%; 0.1% and 0.3%.

The main properties of the investigated emulsions related to density and viscosity are represented in Table 1.

Table 1. General characteristics of the investigated emulsions

Physical characteristic	Type of the investigated emulsion				
	0.5%	1%	5%	10%	20%
Density [kg/m^3]	999	998	990	980	960
Viscosity [mPas]	concentration of gelatine 0.05%				
	0.925	0.893	0.920	0.923	0.925
	concentration of gelatine 0.1%				
	0.902	0.880	0.883	0.923	1.159
	concentration of gelatine 0.3%				
	0.975	0.949	0.931	0.946	1.035
	without gelatine adding				
	0.918	0.919	0.856	0.912	1.048

The viscosity of the prepared samples were measured according to adopted standards at temperature 25°C by using the Ford viscosity cup.

The density of prepared emulsions was defined by pycnometric method.

The stripes of the polypropylene sorbent of the length of 20 cm and the width of 3 cm were submerged with one end into the investigated emulsions to the depth of two centimeters (Fig. 1).

Thus firstly the amount of absorbed emulsion was found due to direct observation and was denoted as measured height, *h*.

Then a value of calculated height h_{obl} was determined according the following formula:

$$h_{obl} = \frac{m}{A \cdot \rho},$$

where *m* is the mass of an emulsion imbibed by the material, kg; *A* is the cross-section of the material (product of width and thickness), m^2; ρ is the substance density, kg/m^3.

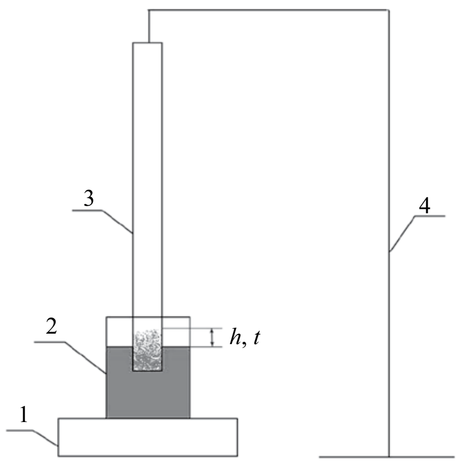

Fig. 1. Scheme of the device for sorption capacity measurement: 1 – analytical balance; 2 – glass with the investigated emulsion; 3 – polypropylene stripe; 4 – stand

The difference between an initial mass of the investigated substance and a mass after fibers sorption was accepted as the mass of an imbibed substance.

The height h_{obl} was determined for seven samples of the polypropylene fibre with assumed thickness in a range from 0.003 till 0.009 m.

The effective thickness was designated as the dependence $h_{obl} = f(t)$, where h_{obl} was the calculated height having the most accurate correlation with experimentally defined value of height.

Processing of the received data was performed using a computer program *Origin*.

The results of research and discussion

According to the results of conducted investigations the effective tickness alters and depends on the dispersed phase concentrations in emulsion and a gelatine fraction.

The graphs in Figs 2–7 describe the dependence of measured (h) and calculated (h_{obl}) heights on time of the spontaneous imbibition in the cases of emulsions with the various dispersed phase concentrations and with/without adding of gelatine. The tickness of the investigated polypropylene fiber was defined as the most effective on condition when a curve of the measured height (h) covered by a curve of the calculated (h_{obl}) approximates data the most accurately.

Such dependence for the emulsion with 1% of the oil phase and gelatine content 0.05% is represented in Fig. 2.

In accordance with received data appropriate correlation between measured (h) and calculated (h_{obl}) heights was observed for material with thickness value 0.009 m.

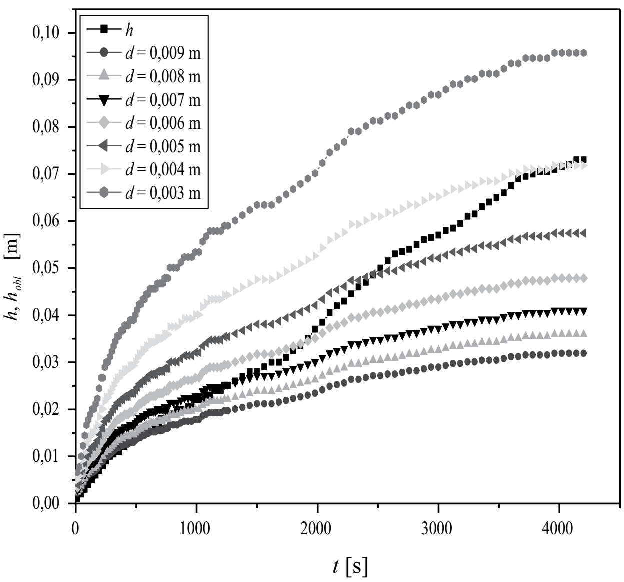

Fig. 2. The diagram of the dependence h, $h_{obl} = f(t)$ for emulsion with the dispersed phase concentration 1% and gelatine fraction 0.05%

The mentioned effective thickness of polypropylene was characteristic for all investigated emulsions with gelatin concentration equaling to 0.05%.

The fibers with thickness 0.005–0.007 m are defined as the most effective in cases, when emulfsifier content was enlarged to 0.1%.

For example, the effective thickness for emulsion with the dispersed phase concentration 0.5% and gelatine fraction 0.1% was equal to 0.007 m and is represented in Fig. 3.

The dependence of measured and calculated heights on time of the imbibition process for emulsions with 5% of the oil phase and gelatin concentration 0.3% is shown in the Fig. 4.

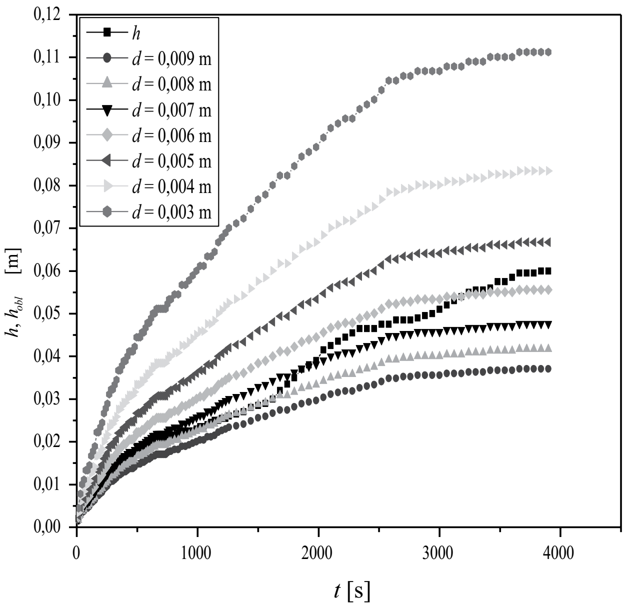

Fig. 3. The diagram of the dependence h, $h_{obl} = f(t)$ for emulsion with the dispersed phase concentration 0.5% and gelatine fraction 0.1%

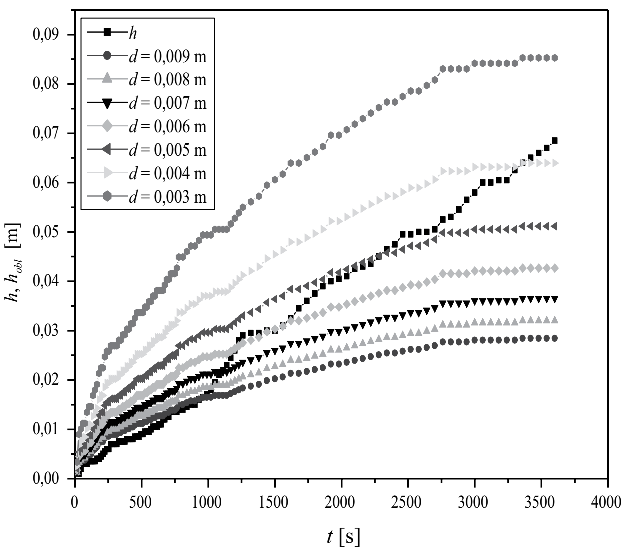

Fig. 4. The diagram of the dependence h, $h_{obl} = f(t)$ for emulsion with the dispersed phase concentration 5% and gelatine fraction 0.3%

According to received data the polypropylene material having 0.009 m of thickness was defined as the most effective for the investigated emulsions with gelatin fraction 0.3%.

The methodology of an effective thickness defining for emulsions without gelatin adding was the same as in the previous occurrence.

Three diagrams submitted below represent the effective thicknesses for emulsions with 0.5%, 10% and 20% of dispersed phase respectively (see Figs 5–7).

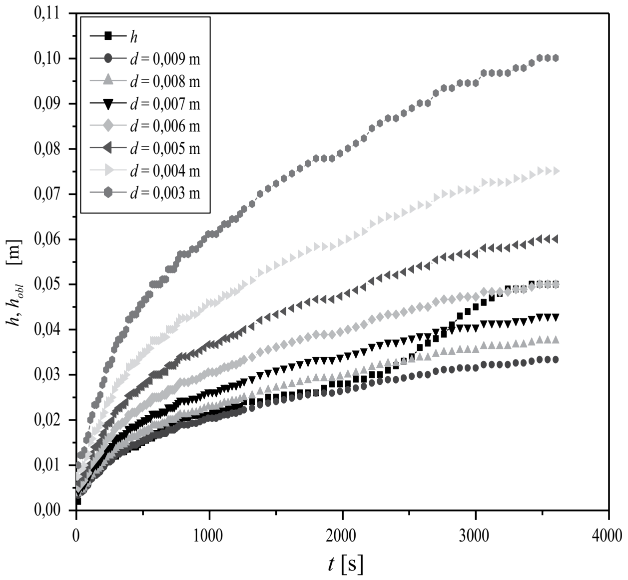

Fig. 5. The diagram of the dependence h, $h_{obl} = f(t)$ for emulsion with the dispersed phase concentration 0.5% without gelatine adding

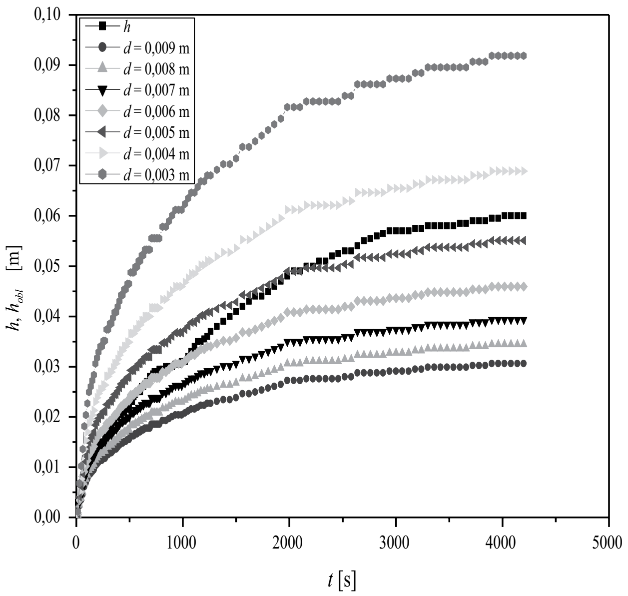

Fig. 6. The diagram of the dependence h, $h_{obl} = f(t)$ for emulsion with the dispersed phase concentration 10% without gelatine adding Thus for emulsion with 10% of the oil phase the effective thickness was equal to 0.007 m and in respect 20% emulsion acquired 0.005 m

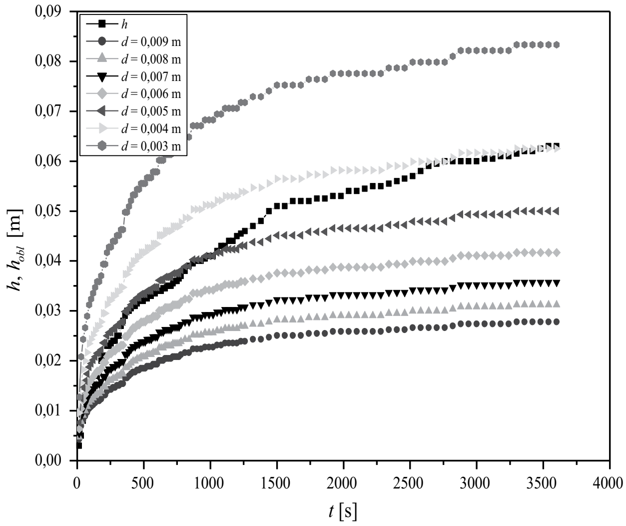

Fig. 7. The diagram of the dependence h, $h_{obl} = f(t)$ for emulsion with the dispersed phase concentration 20% without gelatine adding

Polypropylene material with thickness 0.009 m was defined as the most effective for emulsion with dispersed phase concentration 5%. It was noticed that with increasing of oil phase in the investigated emulsions, the fibers with the less thickness were defined as more effective.

The results received due to investigation of the effective thickness of the polyprotylene material showed that fibers with tickness 0.009 m and 0.005–0.007 m are appropriate for sorbtion of proposed emulsions, opposite to fibers with other values of the mentioned paramenter.

Conclusions

1. According to the results of investigation the effective thickness alters and depends on the dispersed phase concentrations in emulsion and gelatine fraction.
2. In a case of gelatine content 0.1% the effective thickness of the investigated material was in a range of 0.005–0.007 m and depended on the dispersed phase concentration.
3. Taking into consideration the other results it was defined that increasing of oil phase in emulsions caused decreasing values of the effectiveness thickness. Consequently the effective thickness was equal to 0.009.m for emulsion with 0.5% of the oil phase and respectively 20% emulsion acquired 0.005 m.
4. The polypropylene materials with thickness 0.008 m and lower than 0.005 m had less appropriate correlation between measured (h) and calculated (h_{obl}) heights.

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POLIPROPILENO PLUOŠTO NAUDOJIMO EFEKTYVUMAS IŠSILIEJUS NAFTAI TRANSPORTO OBJEKTUOSE

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Santrauka

Straipsnyje nagrinėjama polipropileno pluošto naudojimo avarinio naftos išsiliejimo metu problema. Polipropileno pluoštas naudojamas kaip naftą sugerianti medžiaga. Pateiktos skirtingo storio polipropileno pluošto išsiliejusios naftos sugeriamumo savybės.

Reikšminiai žodžiai: nafta, išsiliejimas, sorbentas, polipropileno pluoštas, sugeriamumas.