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EXPERIMENTAL MODELLING OF MOTOR OIL PENETRATION INTO THE LAND WITH CONSEQUENTIAL INTERACTION WITH POWDER SORBENTS

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Research article

Abstract: Traffic accidents related with the appearance of dangerous materials, i.e. escaping driving fuel and car liquids, often happen on the Slovak roads. Most often, these are crude oil products as diesel, gas and motor oil. Oil products undesirable in contaminations contaminate impacted environment, especially soil, water and air. Units of Fire Department of the SR assisting by the traffic accident related with escaping of dangerous liquids make their identification, localization and consistent liquidation by means of powder sorbents. Experimental modeling of motor oil escaping into the soil with consistent interaction with powder absorbing materials have a goal to achieve the minimization of negative impacts on environment.

Key words: Traffic accident, motor oil, soil, sorbent, experimental modeling.

Introduction

At road accidents related with dangerous materials leakage, various powder sorbents are used in the practice of the Fire Department of the SR, whose members localize and then liquidate the material leakage, by which they eliminate the possible negative impact on environment, especially soil (Šovčíková et al., 2005; Tureková, 2003). By experimental modeling of sorption and desorption processes of the used motor oil as a contaminant into the soil samples with subsequent application of powder sorbent, the process of motor oil penetration into the soil especially in dependence on time, kind, surface of soil and also kind and amount of applied sorbent was studied (Šovčíková et al., 2005; Tureková, 2003; Coneva, 2009; Coneva and Varačka, 2011; Coneva et al., 2011a,b; Zachar, 2010; Marková, 2007).

Experimental study about the interaction of motor oil and sorbent and their penetration into the soil

The Fire and Rescue Services of the SR usually apply in their practice this procedure of using sorbents at the road accidents involving leakage of dangerous liquid substance (MVSR - PHAZZ, Methodical letter No.90 and No.100, 2007):

- At first the sorbent is sprinkled on the surface of the liquid and is being left to have effect until the highest sorption capacity of the used sorbent is achieved.
- During the sorption, the sorbent is stirred with the liquid by a dipper, a rake or a birch broom to accelerate the sorption.
- After saturated sorption of the dangerous substance, the impregnated sorbent is placed into a prepared container for dangerous substances.
- The substance is liquidated by burning in consideration of the absorbed liquid.

In experimental work, it is important to study the process and behavior of motor oil by soil contamination followed by its interaction with sorbents.

The objectives of experiments are (Coneva, 2009; Coneva and Varačka, 2011; Coneva et al., 2011a, b):

- Studying contamination and penetration process of used motor oil into the soil.
- Characterization, determination of significance and specifications of sorbent application for the localization and liquidation of oil product from the soil.
- Determination of the adequacy of using individual kinds of sorbent for soil contaminated by motor oil.

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To achieve these goals, it is necessary to solve these tasks: (Coneva, 2009; Coneva and Varačka, 2011; Coneva et al., 2011a, b):

- To examine the progress of the motor oil penetration into the soil depending on the time and type of the soil (arable/grass).
- To determine the theoretical quantity of applied sorbent in dependence on the amount of used oil based on the sorption capacity of the sorbent.
- To determine experimentally the quantity of applied sorbent used for sorption after oil application in dependence on the time factor.
- To examine the relevance of sorbent applications after the expiry of specified time interval.
- To examine the progress of oil sorption into the sorbent at the soil sample surface in dependence on its type.
- To identify the adequacy of the examined sorbents used for sorption at the soil surface.

Materials and methods

Dangerous substances-pollutants of different state escape not only during transport but also at industrial accidents. There are several options for locating and removal of these dangerous substances, e.g.: organic (toluene, ethylbenzene, xylene) (Jarray et al., 2010) from the natural environment (Gonen and Rytwo, 2006) that are however not suitable for all substances and therefore development and search for new methods are very important. The sorption method which uses modified clay materials has been used for the removal of heavy metals (Cu, Cd, Zn, Ag, Pd, Hg and others) from the aquatic environment (Li et al., 2010). The vapors of volatile organic compounds (benzene, toluene, xylene, naphthalene) are removed from the gaseous environment by sorption method with use of modified clay materials (Houari et al., 2007). Modified clay materials in the form of sorbents were also used for sorption of inorganic Cr (VI) in the form of dichromates from the aquatic environment (Polzin et al., 2011; Pavlovský et al., 2011) and organic pollutants (toluene, xylene, n-hexane) and the results were compared with other sorbents (activated carbon, bentonite, sebenil) (Polzin et al., 2011; Pavlovský et al.,2010; Pavlovský et al., 2009). The known methodologies are dealing with the issues of sorption and desorption of dangerous liquids at the hard surfaces, but this does not correspond to the characteristics and nature of soil surface, since motor oil penetration into the hard surfaces (asphalt, concrete and others) is different in comparison with the soil (ASTM-F 726-8).

Methodology of modeling of the motor oil penetration into the soil with subsequent application of powder sorbent

Special methodology of experimental modeling of the motor oil penetration into the soil with subsequent powder sorbent application has been developed to achieve the set out objectives (Coneva, 2009; Coneva and Varačka, 2011; Coneva et al., 2011a, b; Zachar, 2010; Marková, 2007). This methodology was developed for laboratory conditions with the aim to ensure the objectivity of results and to be close to the real conditions during intervention of the Fire and Rescue Services of the SR.

Materials, samples:

Size of the soil sample: 6.5 x 12 x 6.5 cm,

Amount of oil material [used motor oil]: 75 ml,

Sorbent: LITE-DRI,

Duration of experiment: 1, 15, 30 min,

Ambient temperature: 21 °C,

Atmospheric pressure: 101.5 kPa.

Universal used motor oil in the amount of 75 ml has been used for the experimental research. Soil samples were taken up near the first class road in Žilina region. Kind of soil sample was kambi soil; this type of soil is the most occurring in the Žilina region. We took up two kinds of soil samples - grassy and arable. Soil was taken up in the form of samples - offcuts - and placed into prepared plastic boxes with the size 16.5 x 12 x 6.5 cm (Fig. 1).

Fig. 1 Examined soil sample

Soil samples were taken up nearby the frequented road E-50, Košická Street, in direction Žilina - Martin, near Slovnaft gas station.

The experiment was made on three different sorbents: VAPEX, ECO-DRY PLUS® and LITE-DRI. The experiment will be oriented and described on sorbent LITE-DRI (LITE-DRI,ULD 010, 2011). The results of the experiments of other two sorbents VAPEX, ECO-DRY PLUS® will be published in

other professional, scientific papers. Fig. 2 presents dry sorbent LITE-DRI in Petri-dish and Fig. 3 presents sorbent soaked with motor oil (the pale particles are unsaturated grains of sorbent). Visible dry grains indicate full soaking of the oil liquid with sorbent.

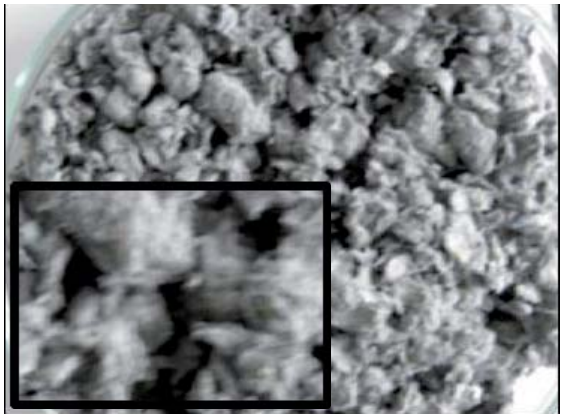

Fig. 2 Dry sorbent LITE-DRI

Fig. 3 Sorbent LITE-DRI soaked with motor oil

Equipment:

For samples collection: spade, small shovel, knife, plastic boxes for samples.

For experiment process: digital weight, stop watch, beaker:100 ml and 800 ml, metal spoon, plastic shovel for sorbent load, ruler, calculator, pen, paper, camera, plastic bags.

Realization process of the experiment

The prepared soil sample was put into translucent plastic box. 75 ml of used motor oil was poured on the soil sample and the time (speed) of its sorption (penetration) was watched. After passing set time intervals of 1, 15, 30 minutes, the application of sorbent on the sample was started. It was gradually sprinkled on the sample and mixed with metallic spoon (replacement of metallic shovels used by firemen) until full sorption (soaking all liquid) into the sorbent at the sample surface of the contaminated soil. The full sorption of all oil liquid is considered in that case if after mixing the sorbent with oil, the unsoaked particles, sorbent grains appear. The amount of the sorbent was calculated on the applied amount of the oil in accordance with the sorption capacity of the sorbent given on the safety card of the sorbent producer (Coneva and Varačka, 2011). The sorption capacity of the LITE-DRI sorbent (32 l) and the weight of the sorbent sample (23.40 g) related (and calculated) to sorption capacity of 75 ml of oil are given in Tab. 1. The amount of applied sorbent can be found out in such a way that the empty beaker is weighted, then the specified amount of sorbent is weighted (Tab. 2, Tab. 3), considering the weight of empty beaker. The weighted amount of the sorbent was then poured on soil samples with oil until full sorption of (soaking) the sorbent with oil. Remainder of the sorbent in beaker was weighted and the measured weight was deducted from the beaker weight with specified amount of the sorbent (Tab. 2, Tab. 3).

Tab. 1 Sorption capacity and weight of applied sorbent LITE-DRI (LITE-DRI,ULD 010, 2011) (Coneva and Varačka, 2011)

Name of sorbent	Sorption capacity of 10 kg sorbent [l]	Weight of sorbent for 75 ml of oil [g]
LITE-DRI	32	23.40

The amount of used sorbent was the result value. Then the amount of applied sorbent on contaminated soil sample with regard to the overall amount of weighted sorbent was specified.

Results and discussion

Results of experimental modeling of the motor oil penetration into the soil with subsequent application of powder sorbent

The results of the experiment are given in tables (Tab. 2, Tab. 3) and graphs (Fig. 6, Fig. 7). In evaluation, we used the basic processes of analysis: induction, deduction, abstraction and generalization. Software MS OFFICE EXCEL was used for evaluation of the table data. Sorbent was applied on five samples after 1 and 15 min. For examining behavior of the sorbent after 30 minutes of exposition, just three soil samples were used because by examining the sorbent after 15 minutes of exposition to motor oil, the oil was practically fully absorbed into the soil sample and so smaller number

of samples was enough for examining. We examined sorbent of organic origin, universal sorption LITE-DRI sorbent, firstly on the sample of arable soil and then on grassy soil which was dramatically drier then with experiment with sorbent ECO-DRY PLUS®. This cellulose-based sorbent has incomparably bigger grains than both other sorbents. Experimental data were scribed; samples were photographed (Fig. 4 - 10) and then processed (Coneva, 2009). The measured values are elaborated in Tab. 2 and Tab. 3 and illustrated in graphs on Fig. 6 and Fig. 7. 23.40 g of sorbent is specified for 75 ml of oil according to sorption capacity of the sorbent declared by the producer. LITE-DRI sorbent applied on motor oil in the arable soil sample is illustrated on Fig. 4, Fig. 5 illustrates its application on the grassy soil sample after 1 minute of exposition to motor oil (Coneva, 2009; Coneva and Varačka, 2011; Coneva et al., 2011a, b).

Fig. 4 and Fig. 5 Sorbent LITE-DRI applied on samples of arable and grassy soil after 1 minute of motor oil contamination

Fig. 6 presents the graph of the comparison of the amount of LITE-DRI sorbent used on arable soil samples after motor oil penetration in dependence on the time of sorbent application. From the results given in Tab. 2 and Fig. 6 follows that after application of 75 ml of oil on arable soil sample it was necessary to apply from 20.00 g to 34.50 g of sorbent after the first minute (Fig. 4).

Tab. 2 Measured values of LITE-DRI on arable soil samples

Sample number	Soil	Time of sorbent application [min]	Amount of Sorbent [g]	Share of all amount [%]	Time of sorption [min]
1	arable	1	34.50	147.40	6.0
2			20.40	87.20	3.0
3			31.90	136.30	4.0
4			22.00	94.00	4.0
5			20.00	85.50	4.0
6		15	4.50	19.20	1.0
7			3.00	12.80	1.0
8			5.80	24.80	1.0
9			4.00	17.00	0.5
10			4.70	20.00	1.0
11		30	2.50	10.70	0.5
12			2.00	8.55	1.0
13			6.00	25.64	1.0

The average of five samples is 25.80 g of sorbent and that is 110, 00 % of the amount declared by the producer (Tab. 1). The comparison graph of the amount of LITE-DRI sorbent used on grassy soil samples after motor soil penetration depending on sorbent application time is on Fig. 7.

Evaluation of measured data from Tab. 3 and Fig. 7 indicates that after application of 75 ml of oil on grassy sample, the amount of used sorbent moved from 3.90 g to 14.80 g (Fig. 5), and this is in average of 9.28 g sorbent from five samples, which is about 40 % of the amount declared by the producer (Tab. 1) (Coneva, 2009; Coneva and Varačka, 2011; Coneva et al., 2011a, b).

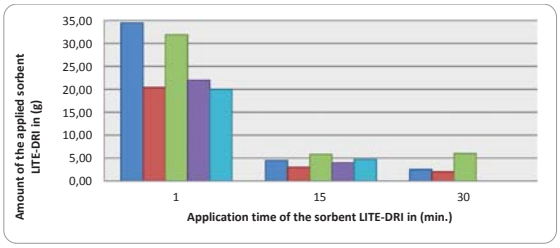

Fig. 6 Comparison graph of applied LITE-DRI sorbent on arable soil samples

We can make a partial conclusion that for the sorption of oil by sorbent after the first minute at the grassy surface of the sample, it was necessary to apply 16.52 g of the sorbent less than in comparison with the arable soil.

Tab. 3 Measured values of LITE-DRI sorbent on grassy soil samples

Sample number	Soil	Time of sorbent application [min]	Amount of Sorbent [g]	Share of all amount [%]	Time of sorption [min]
14	grassland	1	14.80	63.20	1.5
15			3.90	16.70	1.6
16			4.00	17.10	1.8
17			10.30	44.00	2.0
18			13.40	57.30	1.5
19		15	3.70	15.80	0.5
20			4.00	17.10	1.0
21			3.00	12.80	0.6
22			3.80	16.00	1.0
23			3.00	13.00	0.5
24		30	2.90	12.40	0.5
25			2.00	8.50	0.5
26			2.30	9.80	0.5

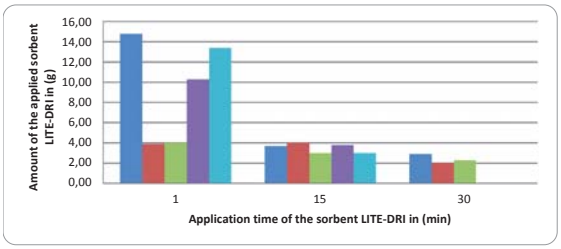

Fig. 7 Graph comparison of applied amount of LITE DRI sorbent on grassy soil samples

After sorbent application in the fifteenth and thirtieth minute, the amount of applied sorbents was much smaller because in most cases almost full or quite full soaking of oil into the grassy and arable soil samples were observed (Fig. 8 and Fig. 9).

After 15 minutes from application of 75 ml of motor oil on arable soil, the amount of applied LITE-DRI sorbent moved from 3.00 g to 5.80 g and the average weight of sorbent was 4.40 g and that is just 19 % from presumed sorbent amount (Tab. 2 and Fig. 6). After 15 minutes from application of 75 ml of oil on grassy soil sample, the amount of applied sorbent moved from 3.00 g to 4.00 g (average 3.50 g) and that is 15 % of the presumed amount declared by the producer (Tab. 3 and Fig. 7) (Coneva, 2009; Coneva and Varačka, 2011; Coneva et al., 2011a, b).

We can make a partial conclusion that after 15 minutes of oil sorption by sorbent at the surface of grassy soil sample, it was necessary to apply about 2.30 g less sorbent than on arable soil.

Fig. 8 and Fig. 9 LITE-DRI sorbent applied on arable and grassy soil sample after 30 minutes from motor oil contamination

After 30 minutes from 75 ml of motor oil application on arable soil sample, the amount of applied LITE-DRI sorbent moved from 2.00 g to 6.00 g and this represent in average 3.50 g what is just 15 % from presumed sorbent amount (Tab. 2 and Fig. 6). After 30 minutes of grassy sample contamination by 75 ml oil, from 2.00 g to 2.90 g of sorbent was applied, in average 2.40 g of sorbent what represents 10 % of the amount declared by the producer (Tab. 3 and Fig. 7) (Coneva, 2009; Coneva and Varačka, 2011; Coneva et al., 2011a, b).

We can make a partial conclusion that after 30 minutes of oil sorption by sorbent at the surface of grassy soil sample, it was necessary to apply about 1.10 g less sorbent than on arable soil.

From the above mentioned follows that after 15 and 30 minutes of arable soil samples contamination, it was necessary to apply more sorbent (4.40 g and 3.50 g: Tab. 2, Fig. 6) than in grassy soil samples contamination (3.50 g and 2.40 g; Tab. 3 and Fig. 7).

We can see on Fig. 4 and Fig. 5 visibly observable applied sorbent after one minute from arable and grassy oil contamination. After 15 and 30 minutes of sorbent application this amount is minimal, there was almost no observation of motor oil infiltration on sorbent and the most of sorbent particles stayed dry (Fig. 8 and Fig. 9).

Sorption (infiltration) time of used motor oil on LITE-DRI sorbent by arable soil samples was in the range from 0.5 to 6 minutes, in average it represents 2.15 minute (Tab. 2). Sorption time interval on grassy soil samples was realized from 0.5 to 2 minutes, in average 1.04 minute (Tab.3). We assumed that the values are particularly depending on applied sorbent amount, surface of concrete sample and the speed of sorbent application (Coneva, 2009; Coneva and Varačka, 2011; Coneva et al., 2011a, b).

Concerning the grassy soil sample, the important factors are its condition (wet, dry and other), surface and sample volume. This concerns the amount of air holes and soil sorption ability but also the ability of the grass interaction with oil, lower amount of used sorbent, and sorption time. Arable soil, after some time, completely absorbs (soaks) motor oil (Fig. 4 and Fig. 8) but grasses on grassy soil samples, also after some time, catch some motor oil volume that decreases the probability and consequence of soil and groundwater contamination (Fig. 5 and Fig. 9) by the contaminant. Even though some amount of oil remains on grassy sample surface, it is necessary to decrease the amount of sorbent for its sorption because part of oil is absorbed (bound) by grass mostly in short time interval of 1 minute - the contrast disappears after 15 and 30 minutes.

Conclusion

Powder sorbents are mostly used by the Fire and Rescue Services of the Slovak Republic at traffic accidents related with the leakage of dangerous oil materials to ensure their localization and liquidation. Usage of LITE-DRI sorbent for contaminant sorption from the arable and grassy soil has its purpose only in short time interval, the best at the moment of contaminant leakage into the soil at the traffic accident. When we extend the time interval (15, 30 and more minutes), the importance of sorbent usage significantly degrades and the ecological consequences rise: groundwater and soil pollution is higher. Bigger amount of grass at soil surface is able to tie in more oil contamination on itself and by it to decrease applied sorbent amount - most of all in fast intervention.

The results probably depend also on sample wetness wittiness, kind of soil and sorbent, state of soil (for example: frozen, dry and others), climatic conditions, time factor (speed and availability of information and intervention accomplishment with the goal to localize and thereafter liquidate the contamination), human factor (ability to evaluate the situation correctly and to choose correct and the fastest method of tactical intervention), therefore it is important to proceed in advanced research. The results of the experiments with other two sorbents VAPEX, ECO-DRY PLUS® and their comparison will be published in professional, scientific journals and scientific conferences. Processed and published results are and will be available in the near future in the form of professional scientific publications, the final report from the project to the science public and training. The project was realized for two years (2010 - 2011) and completed in 2011. At present the continuation and expansion of research in this subject is not supposed (Coneva et al., 2011a, b).

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