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ANALYSIS OF THE MIGRATION OF A POLLUTANT IN THE SOIL STRUCTURE

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Abstract

This paper presents a study on the migration into a soil structure of a pollutant, a liquid petroleum product. Accidental pollution with a liquid petroleum product can also be considered to crack a transport pipeline. This leads to the displacement of the pollutant in the soil structure, both horizontally and vertically. The study presents an analysis of the migration velocity in the soil structure, with certain physical properties, of both the soil and the pollutant petroleum product. The penetration of petroleum products to a certain depth in soil is influenced by its humidity, grain size and density, pollution intensity, viscosity and pollutant density. It was possible to calculate for the first time at the experimental laboratory level the depth of penetration of the pollutant.

Keywords: *contaminated, diesel oil, pipeline, soil*

Introduction

The soil pollution with oil products is one of the most obvious environmental problems facing Romania in recent years, given the increasing and intensified use of these substances to meet the energy needs. It can be noticed that both in Romania and in the world every year there are reported a multitude of accidental or deliberate spills of oil products on the soil or in waters, which cause economic, social and environmental problems. Ensuring soil quality protection as a means of increasing soil resources and protecting the environment, among other things, includes the use of depollution processes and technologies to neutralize or block the flow of pollutants and to ensure the desired efficiency and enforcement of the protection legislation soil quality (Neag 1997).

This work is part of an extensive study that aims to highlight the influence of soil and pollutant properties in case of accidental spillage.

The direction and speed of displacement of the pollutant depend mainly on its viscosity and the permeability of the soil. The main force acting on the pollutant is gravity. Therefore, if the soil is permeable, the pollutant infiltrates into the predominant soil after a vertical component. There is also a lateral impregnation of the pollutant, due to the dispersion, which is controlled by the soil porosity. Advancing to the aquifer, the pollutant can be filtered by soil particles, can be absorbed, volatilized, precipitated, biodegraded and to a lesser extent, hydrolyzed, oxidized, reduced, or even stopped by an impermeable barrier (Popa & Negoita 2016a, Popa & Onutu 2016b, Popa et al 2017, Patrascu et al 2005).

Materials and Methods

At laboratory level, it was attempted to simulate the real accidental cracking environment of a pipeline carrying a liquid petroleum product. How the pollutant penetrates into the soil structure is responsible for the physical properties of the two components: soil - pollutant.

The experimental assembly consisted of a transparent vessel in which a cracked pipe was buried in a soil layer. By this it circulated controlled quantity of petroleum product. Measurements have been made on the stains seen after the controlled pollution.

The migration velocities of the pollutant in the soil structure could thus be set at different measuring times.

As ascending and descending speeds are variable over time, the calculation was incremented for each time interval between two consecutive measurements. The values obtained are used for the calculation of average speeds in each time interval. Experimental scheme is shown in fig. 1.

Figure 1. Experimental scheme

The geometric characteristics of the experimental glass box and the soil layer are shown in Table 1.

Table 1. Geometrical characteristics of the experimental glass box

Materials	Height, cm	Width, cm	Length, cm	Volume, cm^3
Box	13	22	32.5	9295
Soil	8.5	22	32,5	6078

Results and Discussion

In the experimental experimental glass box was initially discharged a volume of 20 cm^3 of petroleum product and the stains observed on the front wall were measured. When the dimensions of the stain remained constant, after 60 minutes, the volume of 20 cm^3 was added. Table 2 shows the variation of the horizontal petroleum product spot, the horizontal product stain variation is shown in fig. 2, while fig. 3 shows the variation of the vertical stain.

Table 2. Horizontal petroleum product variation

Crack size, mm	Volume of spilled oil product, cm3	Time, min	Width of stain petroleum product, cm
1,5	20	15	10
		30	10,5
		45	10,8
		60	11
	20+20	75	11,3
		90	12,3
		105	13,8
		120	13,9

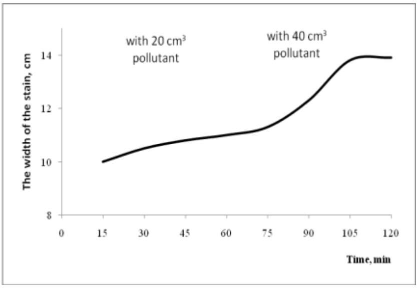

Figure 2. Variation of the width of the stain in time

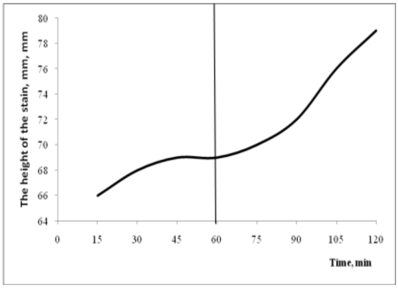

Figure 3. Variation of the height of the stain in time

Table 3. Vertical petroleum product variation

Time, min			15	30	45	60	75	90	105	120
Petroleum product	Soil	h_a, mm	4	6	7	7	8	10	14	17
		h_d, mm	62	62	62	62	62	62	62	62

Figure 4. Experimental installation after pollution

Fig. 4 presents petroleum product stain images visible in the experimental installation at the end point of time, while the ascending velocity variation is shown in fig. 5.

In order to express the speed of movement of the pollutant vertically in a soil, the measured values for the Δh_a and Δh_d heights of the formed pollutant fronts were presented. They are presented in table 4.

The ascending – wa – and descending velocities – wd – are calculated according to the heights of the upward motion liquid ha and descending hd at different time points from the start of the experiment.

$$w_a = \frac{\Delta h_a}{\tau_m}, \quad \text{mm/min} \qquad (1)$$

$$w_d = \frac{\Delta h_d}{\tau_m}, \quad \text{mm/min} \qquad (2)$$

Table 4. Variation for Δh_a and Δh_d

$\tau_f - \tau_i$, min			15-0	30-15	45-30	60-45	75-60	90-75	105-90	120-105
$\Delta\tau = \tau_f - \tau_i$, min			15	15	15	15	15	15	15	15
τ_m, min			7.5	7.5	7.5	7.5	7.5	7.5	7.5	7.5
Petroleum product	Soil	Δh_a	4	2	1	0	1	2	4	3
		Δh_d	62	0	0	0	0	0	0	0

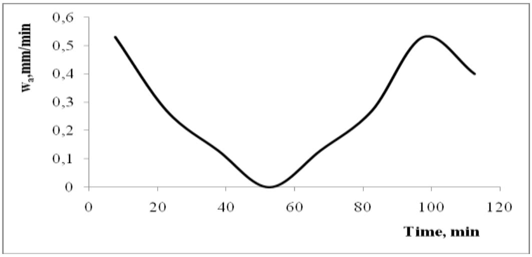

Figure 5. The ascending velocity variation

To determine the maximum penetration depth (H) of the pollutant into the soil, rigorous calculation methods were applied in the unsaturated zone (Neag 1997).

$$H = K \cdot \frac{1000 \cdot V_i}{A \cdot R \cdot k}, \text{ m} \qquad (3)$$

where, K- specific coefficient for pollutant, dimensionless, A-the infiltration surface, m^2, R-retention capacity, l/m^3, k-correction coefficient, dimensionless, Vi - volume of pollutant discharged, m^3.

The results obtained are presented in the table 5. It is observed that for the experimental installation studied the maximum penetration depth of the soil in the soil, H, is 1.46 m.

Table 5. Dimensions calculated for penetration depth

Calculated sizes	Symbol	Value
Retention capacity, l/m^3	R	5
Volume of pollutant discharged, m^3	V_i	$40 \cdot 10^{-6}$
Specific coefficient for pollutant	K	400
The correction coefficient	k	0,5
The infiltration surface, m^2	A	$95.91 \cdot 10^{-4}$
The maximum penetration depth, m	H	1.46

Conclusions

The evolution of the pollutant in the soil is influenced by the soil and pollutant properties. When polluting the soil with liquid petroleum products, the formed stain develops both horizontally and vertically. The experiment initially polluted with a volume of 20 cm^3, and a decrease in ascending speed was observed over time, after which, at a further 20 cm^3 pollution, it increased to a maximum and then dropped again. For this experiment it was possible to calculate the maximum penetration depth of the pollutant in the unsaturated zone, 1.46 m.

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