Acta Montanistica Slovaca Ročník **9** (2004), číslo **3,** 172-175

Influence of soil parameters on depth of oil waste penetration

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Abstract

A measurement post for testing propagation of hydrocarbon contamination in a model of a near-surface soil layer and its remediation, are characterized in the paper. Generalized results of laboratory observations require meeting similarity criteria of the laboratory and actual processes. These requirements were used when designing the measurement post. A successful attempt to match a theoretical model describing oil products filtration necessitates certain conditions, e.g. homogeneity of the physical model of soil and characteristic of the course of the analyzed processes.

Key words*: oil waste penetration, soil parameters, soil models, laboratory measurements*

Introduction

A measurement post for testing oil products propagation in a near surface soil layer and its further remediation, was prepared at the Faculty of Drilling, Oil and Gas, AGH-UST. According to the assumptions, analyses were made for a few pollutant fluids of different properties, propagating in various soil models. The first assumption can be met by repeating the soil contamination process (after prior remediation) with various hydrocarbon mixtures. The second condition requires preparing a special measurement post with some independent soil models. Assumption of similarity criteria for the laboratory and field conditions necessitates an analysis of parameters of aggregates - components making up a representative model of soil. On the other hand, the model should also be homogeneous as far as its filtration-reservoir properties are concerned. Only then a sufficiently correct theoretical model, describing the processes taking place in the laboratory post, could be made.

Measurement post design

Analyzing actual processes with the use of a laboratory model, usually smaller in size, where usually a limited number of factors interact, the similarity between laboratory and actual processes is of special interest. The similarity criterion is a basic condition, owing to which laboratory conclusions can be generalized. Similarity between laboratory and actual processes corresponds to the equality of differential equations, characterizing the analyzed regularities, usually without a necessity to preserve the same variability ranges of a group of its parameters.

Determination of the whole class of all feasible solutions (processes in real conditions) and subclasses of processes taking place at the laboratory post lies in making additional assumptions, the so-called unambiguity conditions, which usually encompass the following issues:

1. geometrical characteristic of the process, e.g. determination of geometrical size of the model, geometry of the processes taking place, etc.
2. basic conditions describing the analyzed system, e.g. characteristic of external and internal parameters of the system, e.g. temperature, pressure, determination of the initial state of the system,
3. properties of the environment, e.g. basic physicochemical properties of the medium and fluids used,
4. boundary conditions, e.g. conditions at the borders of the model, factors, directions and character of effects taking place there.

In view of the similarity analysis, the laboratory stand design should take into account the following fundamental aspects:

5. preparation of a suitable soil model,
6. selection of suitable hydrocarbon pollutants,
7. establishing proper geometrical parameters of the measurement post.

Soil model should have appropriate petrophysical properties, close to the actual ones. Analogously, properties of hydrocarbon pollutants should be similar to those encounted in field conditions.

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(Recenzovaná a revidovaná verzia dodaná 4. 10. 2004)

Geometrical size (minimum) of soil model result from the dimensionless criterion parameters π_1 and π_2 determined with the formula (Fąfara, 2004):

$$\frac{\sigma \cdot \sqrt{n}}{\Delta p \cdot \sqrt{k}} = \pi_1, \frac{\sigma}{k \cdot |gradp|} = \pi_2 \qquad (1)$$

where: σ is surface tension of analyzed fluid, n is porosity of soil model, k is soil permeability, and p is pressure responsible for fluid filtration in soil model.

If the formula for atmospheric air and typical values of criterion parameters for oil products as well as boundary values of criterion parameters π_1 and π_2 (Gimatudinov, 1971) are substituted to (1), then the dependence of minimum geometrical size of the soil model on its permeability would be the following:

$$\begin{cases} h \geq \dfrac{2.46 \cdot 10^{-6}}{\sqrt{k}} \\ l \geq 1.31 \cdot 10^{11} \cdot h \cdot k \end{cases} \qquad (2)$$

Applying Kozeny law for loose soils (Plewa & Plewa, 1992), the similarity criteria can be related to the equivalent grain diameter:

$$\begin{cases} h \geq \dfrac{1.41 \cdot 10^{-4}}{d} \\ l \geq 5.65 \cdot 10^{3} \cdot d \end{cases} \qquad (3)$$

These dependences are graphically presented in Fig. 1.

If h = 1.25 m, then the equivalent diameter d = 0.11 mm, and consequently, the half width of soil model is l = 0.62 m. Hence the conclusion that an individual soil container can be approximately of cubic shape (1.25 m of side). Then the measurement post will enable testing oil products propagation in soils of equivalent grain diameter value not less than 0.11 mm, which is typical of dusty soils.

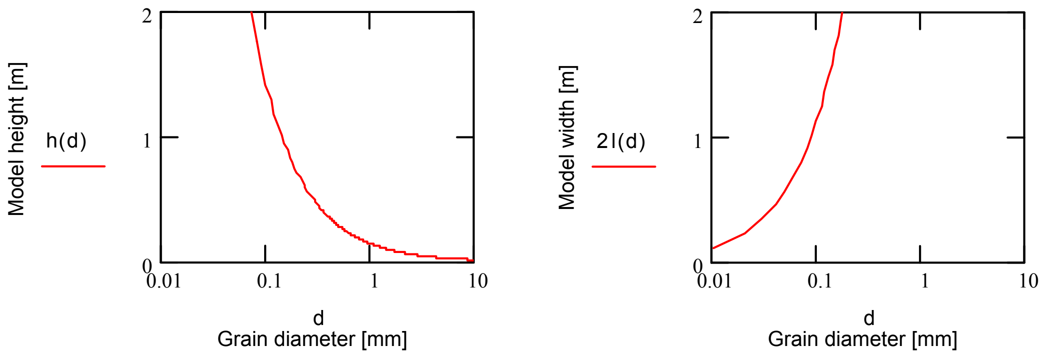

***Fig. 1** Dependence of soil model height and width on grain diameter.*

Description of measurement post

Measurement post consists of three independent containers for various soil models. Each of the containers is of cubic shape (1.25 m of side). A number of perforated PCV tubes were installed in each container, enabling a direct analysis of soil gases composition. The Dräger method was used for detecting hydrocarbon vapours, and for taking samples of contaminated soil for a laboratory analysis of hydrocarbon content with the IR adsorption method. The pattern of tubes is presented in Fig. 2. Symbol A stands for seven horizontal perforated tubes for testing vertical propagation of contaminations, whereas symbol B denotes three horizontal perforated tubes used for horizontal monitoring. Symbol S stands for sampling tubes for soil to be analyzed for hydrocarbons content.

Z denotes the perforation range of horizontal PCV tubes, whereas P is the top perforation range of vertical PCV tubes and P_0 is the bottom perforation rage of vertical PCV tubes.

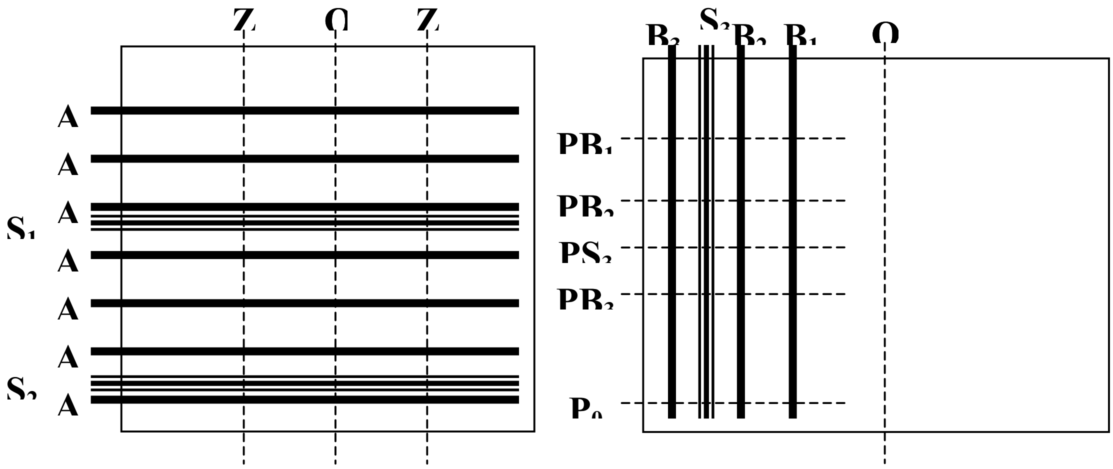

Fig. 2 *Vertical section of the laboratory measurement post.*

Properties of soil model

To assess the properties of a soil model in view of criterion (2), porosity and granulometric (grain size distribution, Figs 3 to 5) analyses were made. On this basis the permeability coefficient value was estimated (Plewa & Plewa, 1992). The measurement and calculation results are presented in Table 1.

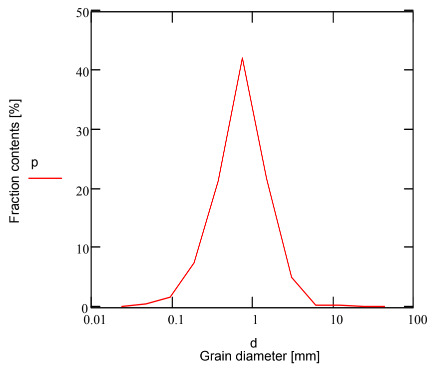

Fig. 3 *Distribution of grain size in the first soil model.*

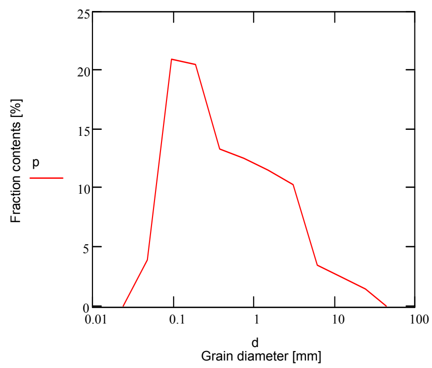

Fig. 4 *Grain size distribution in the second soil model.*

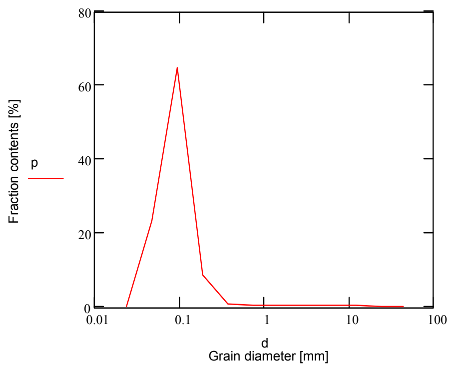

Fig. 5 *Grain-size distribution in the third soil model.*

Tab. 1. Results of assessment of selected parameters of soil models.

Parameter	**Soil model**		
	1	**2**	**3**
Median (mm)	0.730	0.342	0.088
n (%)	36.1	38.8	41.7
k (D)	114.9	22.3	4.12

Summing up

The prepared soil models are considerably representative for a relatively large group of cases, from sands (model 1) to sand-dusty soils (models 2 and 3). Bearing in mind the petrophysical parameter values of soil models, the similarity conditions for laboratory and actual processes are met for the assumed size of the measuring post.

Acknowledgements: this work was prepare in grant WWNiG AGH no. 18.25.190.270.

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