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Laboratory Studies for a Soil Polluted from an Abandoned Well

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Abstract

In the present paper there are presented comparative studies of laboratory for soil sampling in the area of an abandoned well. The contaminated soil samples have been subjected to thermal methods (combustion and desorption) and successive extraction with solvents. For the three methods for decontamination it has been determined the decontamination degree. The comparison of the obtained results could be achieved only by means of analysis of the type of soil polluted. Thus, there have been compared the obtained results and have been determined the advantages and disadvantages of applied methods.

Key words: *soil, decontamination, oil products, well*

Introduction

Petroleum products are a mixture of hydrocarbons, volatile and non-volatile, reaching the soil surface by pouring or storage, together with other waste. They can contaminate the soil surface, the unsaturated area and underground waters, being a long-term source of pollution [4], [8]. It is known that, worldwide, an important share is represented by thermal and biological methods of decontamination of soils contaminated with hydrocarbons [2], [4]. There were also studied other methods of remediation, and phytoremediation is one of them [1], [3]. This paper is a part of an extensive study of the authors on pollution and remediation of soils contaminated by petroleum products [6]. The analysis of depolluting process of soils contaminated with liquid petroleum products highlights the advantages and disadvantages of each method. In this paper, special attention was given to thermal decontamination methods: combustion and thermal desorption and one of the chemical processes, extraction with solvents.

Experimental Part

The exploitation of crude oil deposits is performed using oil wells. The well represents a mining work surface, with special equipment that performs communication between the production and surface layer. The wells are made by drilling with rotary hydraulic methods on land and sea, from fixed or floating platforms, which turn ordinary vertical, but may continue with sloped or multiple routes. The complexity of crude oil extraction activities cause high level pollution, including, besides pollution sources resulted from human activities, specific pollution sources, the latter being more spread and with a long-lasting negative impact on the environment; those

sources are identified, alongside with the possible ways of acting on the ecosystems. The implementation of technologies that ensure environmental protection takes into account the remembers the abandonment of drilled wells, greening and play their original land utilities.

Restoring the land to the circuit in which it belonged, before the process of drilling occurred, includes the reconstruction process, as well as agro-pedo-ameliorative developments which ought to overturn in time the negative externalities of two major factors: saltwater and oil. Evidence for analysis from a disaffected probe has been chosen. Evidence of contaminated soil has been taken and analyzed through 3 methods.

Evidence of fresh, unpolluted soil, situated near the assessed area has also been taken; they served as witness evidence and also underwent the decontamination process. Samples from different surface depths (10 cm and 30 cm) were taken. After the analysis, it was concluded that the mixture of what had been previously used as evidence could be used as a single sample. The results are an average of all determinations done for each and every decontamination method.

Soil decontamination with oil products through the combustion method consists of the burning-out of the pollutants with oxygen from the air supply; this method is recommended for soils which have been contaminated with heavy oil products. Through the combustion of the soil mixture with oil products, the pollutants and the organic material from the soil structure are removed completely.

Thermal desorption is recommended as a decontamination method when the soil has been contaminated with volatile or semi-volatile compounds. Usually, this process is composed of 2 distinct steps. The first is the volatilization of the pollutants via heating of the soil, and the second consists of handling the resulting gases in order to separate and concentrate the pollutants.

Extraction of the oil products was done with the Soxhlet apparatus. Two solvents were used, petroleum ether and benzene, and the extraction was done successively with them.

Results and Discussions

The witness soil sample was characterized first by granulometry or grain size, permeability and capillary action and results are presented below [7].

Soil grain size represents the percentage distribution of the size of soil particles.

The principle of the method is to separate soil particles through the sieve having the mesh size decreasing. Measurement results are shown in Table 1.

Table 1.The particle size distribution of the soil

	Sive 1 d_1=1.5 mm	Sive 2 d_2=0.49 mm	Sive 3 d_3 =0,2mm	Sive 4 d_4= 0.12mm
m_i,g	42	45	10.2	2.8
%	42	45	10.2	2.8

The permeability of soil is its property to allow flow through the structure of a fluid (liquid or gas). This property is dependent on the spaces between the aggregates and robust physicochemical links established between them and the fluid molecules that cross the ground.

Table 2. The permeability and retention capacity (RC) of the clean soil analyzed for water

No.	Specified size	Value
1.	m_0,g	368.2
2.	H_{strat},cm	12.5
3.	d_{strat},cm	4
4.	V_{strat},cm^3	157
5.	$V_{15\ min}$, cm^3	36
6.	$V_{30\ min}$, cm^3	81
7.	$V_{45\ min}$, cm^3	116
8.	$V_{60\ min}$, cm^3	151
9.	m_f,g	448
10.	$P_{15\ min}$,cm^3/h	144
11.	$P_{30\ min}$,cm^3/h	162
12.	$P_{45\ min}$,cm^3/h	154.67
13.	$P_{60\ min}$,cm^3/h	151
14.	P_m, cm^3/h	145.42
15.	RC,kg/m^3	508.28

The capillarity of a layer of soil is the ascension phenomenon of a liquid through the spaces (pores) between aggregates solid constituent. Capillary forces have an intensity given by the shape and size of capillary channels by the composition and state of solid and liquid parts in contact.

Table 3. The measured values for determination of capillarity of the clean soil

No.	Height wet layer	Value
1.	$H_{u10\ min}$,mm	250
2.	$H_{u20\ min}$,mm	400
3.	$H_{u30\ min}$,mm	480
4.	$H_{u40\ min}$,mm	500
5.	$H_{u50\ min}$,mm	600
6.	$H_{u60\ min}$,mm	650

Based on the values that are summarized in table 3 will plot the moisture front height variation with time.

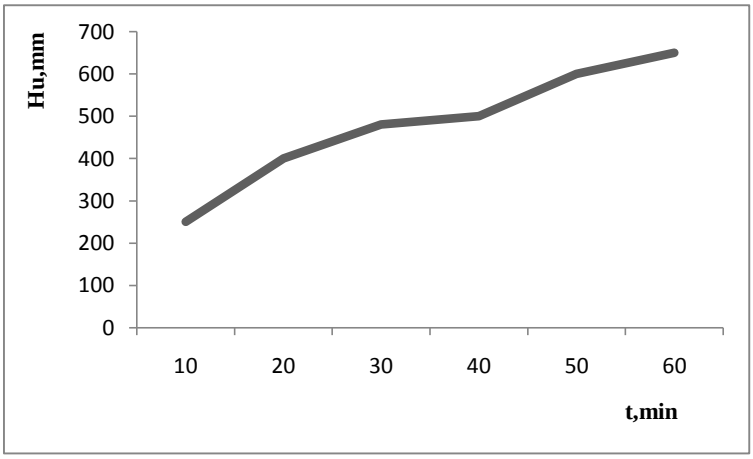

Fig.1. Front height variation of moisture with time

Knowing these two physical properties of the analyzed soil gives in formation about its possibilities of being accidentally polluted. The degrees of depollution of the methods that will be applied can be interpreted having these properties. The movement of the pollutant in the soil depends both on the physical proprieties of the pollutant and physical properties of the soil and nonetheless on its pedological structure.

All decontamination methods have been applied in the laboratory and experimental results are presented below.

The remediation of soils that were contaminated with petroleum products by the combustion method consists of burning oxygen derived from an air pollutant, considering the degree of remediation reaching 100%.

Table 4. Results from soil remediation by the combustion method

No.	Specified size	Clean soil sample	Polluted soil sample
1.	Quantity of polluted soil, g	-	125.4
2.	Quantity of clean soil for combustion, g	100	-
3.	Quantity of soil after combustion,g	98	104.78
4.	Quantity of organic material,g	2	2.51
5.	Quantity of petroleum products+organic material,g		18.11
6.	Quantity of petroleum product, g	-	18.11-2.51=15.6
7.	Petroleum product, % mass	-	12

Table 5. The quantities measured and calculated in the experiments of thermal desorption

No.	Specified size	Clean soil sample	Polluted soil sample
1.	Type of soil	Clean sample	Polluted soil
2.	Type of pollutant	–	Liquid petroleum product
3.	Concentration pollutant, c_o, %	0	12
4.	Temperature, ^oC	300 - 400	300 - 400
5.	Desorption time, minute	20	20
6.	Gas consumption, liter	10	19
7.	Quantity of sample, g	51	124
8.	Quantity of sample after desorption, g	50	51
9.	Organic material lost, %	1.96	1.96
10.	Organic material lost + petroleum product lost, after desorption, %	-	58.9
11.	Degree of remediation,%	-	56.94
12.	Petroleum product lost after desorption, % mass	-	6.83

Table 6. Results obtained from the extraction process

No.	Specified size	Clean soil sample	Polluted soil sample
1.	Quantity of sample, g	20	21.80
2.	Quantity obtained with petroleum ether, g	0.016	0.60
3.	Quantity obtained with benzene, g	0.028	0.40
4.	Total quantity after extraction,g	0.440	1.00
5.	Petroleum product lost after extraction, % mass	0.220	4.36

Soils that were de-polluted by thermal methods have their structure and composition greatly affected due to high temperatures which were maintained. By complete disappearance, in case of the remediation, of organic materials by combustion and by major transformations that are supported in case of the remediation by thermal desorption, it is reduced the whole seed potential of that specific soil. For the analyzed samples, not knowing pollutant concentrations, it was considered that the combustion method has a degree of remediation of 100% and this way we were able to establish a concentration of pollutant in the original samples. By subjecting the same samples to decontamination by successive extractions, it was found that it is obtained a

concentration of the pollutant in the sample much lower compared to the results obtained by thermal methods.

For characterizing the polluted soil samples it was considered that the combustion method ensures a degree of remediation of 100%, which allowed the determination of the pollutant concentration of 12%. For this reason, the degree of remediation for the other methods could be calculated and they are presented in table 7.

Table 7. Decontamination degrees performed

Organic material lost, % mass		Petroleum product lost, % mass	Decontamination degree, % mass
Extraction	0.22	4.36	36.33
Combustion	2	12	100
Thermal desorption	1.96	6.83	56.94

Conclusion

As it can be seen from the results of the analysis, the particle size of the ground structure (containing large aggregates through a sieve with apertures past maximum) permitted the penetration of the pollutant in the structure. For this reason, we can explain that you cannot achieve high degrees of remediation by solvent extraction and thermal desorption due to the presence of heavy petroleum compounds. They could be destroyed at high temperatures, applying combustion or incineration. It is possible that, using other solvents, the degree of remediation would increase. On a soil profile, the texture may be uniform or may differ appreciably from one horizon to another, depending on the chemical and mineralogical composition, and the nature of pedogenesis processes. When the texture varies from one horizon to another because of the heterogeneity of constituent materials, the soil has a contrasting texture. For characterizing the polluted soil it was considered that the combustion method ensures a degree of remediation of 100%, which allowed the determination of pollutant concentrations in samples. It has been established that this concentration was 12%. For this reason, the degree of remediation for the other methods could be calculated. It has achieved a degree of remediation by successive extraction with solvents of 36.33% and 56.94% for thermal desorption.

The results confirm that the incineration remediation method can be applied when the pollutant is represented by heavy hydrocarbons, which provides a maximum degree of remediation. This type of pollutant is specific in the areas where there are abandoned wells.

References

1. Boros, M.N., Micle, V. – Study on the application of phytoremediation of contaminated industrial sites, *Land Reclamation, Earth Observation & Surveying, Environmental. Engineering*, Vol. III, Bucharest, 2014, pp. 99-106.
2. Chaineau, C.H., Yepremian, C., Vidalie, J.F., Ducreux, J., Ballerini, D. – Bioremediation of a Crude Oil – Polluted Soil. *Biodegradation, Leaching and Toxicity Assesments, Water, Air and Soil Pollution*, Vol.144, Issue 1, April 2003, pp. 419-440.

3. Huang, X.D., Alawi, Y.El., Penrose, D.M., Glick,B.R., Greenberg, B.M. – A multiprocess phytoremediation system for removal of polycyclic aromatic hydrocarbons from contaminated soils, *Environ. Pollut.* **130**, pp. 465- 476**.**
4. Neag , Gh – *Depoluarea solurilor şi apelor subterane*, Editura Casa Cărţii de Ştiinţă Cluj-Napoca, 1997.
5. Nwadinigwe, A., Onyeidu, E. – Bioremediation of Crude Oil Polluted Soil Using Bacteria and Poultry Manure Monitored through Soybean Productivity, *Pol. J. Environ. Stud*., Vol.21, No.1, 2012, pp. 171-176.
6. Popa, M. – Laboratory studies on the simulation of accidental pollution of soils, *Land Reclamation, Earth Observation &Surveying, Environmental Engineering,* Vol. IV, Bucharest, 2015, pp. 116-119.
7. Patrascu, C., Negoita, L., Popa, M. – *Depoluarea solurilor contaminate cu produse petroliere, Lucrări de laborator,* Editura UPG – Ploieşti, 2008.
8. Rojanski, V. – *Protecţia şi Ingineria Mediului*, Editura Economică, Bucureşti, 1997.

Studii de laborator pentru solul poluat de la o sondă abandonată

Rezumat

În prezenta lucrare sunt prezentate studii comparative de laborator pentru probe de sol din zona unei sonde abandonată. Probele de sol contaminate au fost supuse unor metode termice (combustie și desorbție) și extracție succesivă cu solvenți. Pentru cele trei metode de decontaminare s-a determinat gradul de depoluare. Compararea rezultatelor obținute ar putea fi realizată numai prin intermediul analizei tipului de sol poluat. Astfel, s-au comparat rezultatele obținute și au fost determinate avantajele și dezavantajele metodelor aplicate.