AN ASSESSMENT OF THE EFFECTS OF CRUDE OIL POLLUTION ON SOIL PROPERTIES

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Abstract
Pollution caused by crude oil is the most prevalent problem in the environment. The release of crude oil into the environment by oil spills is receiving worldwide attention. The effect of crude oil pollution on soil properties was investigated by achieving a case study in Perisoru, Braila County. It has been achieved a profile until 120 cm and soil samples were collected according to the methodology and analyzed for some physical and chemical properties. In case of physical analysis, the values obtained for granulometric fractions were not influenced by the presence of crude oil. Results obtained showed variation in chemical properties of soil. Organic carbon increased from 2.23% for an unpolluted soil to 5.51% in polluted soil. C/N ratios increased from 13.01 for an unpolluted soil to 20.54 in polluted soil. Mobile phosphorous and potassium registered in polluted soil similar values with the one characteristic for unpolluted soil. Crude oil at high pollution levels inhibited the growth of crops.

Keywords: crude oil, pollution, soil properties, Braila County.

1. INTRODUCTION

Human technological and scientific advances have caused environmental changes that are impossible to evaluate and fully comprehend. Our ability to change the environment has increased faster than the ability to predict the effect of that change. Pollution of the environment is one of the major effects of human technological advancement. It results when a change in the environment harmfully affects the quality of human life including effects on animals, microorganisms and plants.
Hence Odewunmi [4] defined pollution as the presence in significant amounts of an extraneous material, which may be solid, liquid, or gas in a particular location. The contamination of the environment (mainly terrestrial and aquatic) by crude oil is therefore referred to as crude oil pollution and it is estimated that 80% of crude oil pollution is as a result of spillage [5].
Romania still depends largely on crude oil for income earnings. Crude oil spillage is also a very common problem in the country. There is therefore a need for continuous research on the problems associated with pollution resulting from spillage and its effects on the soil environment which has a negative impact on crop growth on it. Hence this particular study had as its main objective to examine the effects of crude oil on soil physical and chemical properties [3, 7].
Currently, about 80% of lands are contaminated/polluted by products of petroleum origin (hydrocarbons, solvents, etc.) used as an energy source in the oil industry, as well as chemicals. There are a variety of pollutants affecting soil and subsoil, such as fuel and oil products, hydrocarbon residues, crude oil, other products resulting from the operation (saturated and unsaturated aliphatic hydrocarbons, and the monocyclic and polycyclic aromatic).
These types of products (mainly hydrocarbons) have a harmful risk, affecting the quality of groundwater, which becomes unfit for use for a long time (drinking water, irrigation and different industrial uses). It also poses risks to human health, biological environment and vegetation, aromatic compounds having a strong feature of mutagenic and carcinogenic and, not least, affect the environment security, presenting risks of explosion and fire, when the floating oil reach the groundwater in the basement of various buildings [1, 6].

2. MATERIAL AND METHOD

The perimeter in which has been set for the case study was chosen according to the massive pollution of cracking a crude oil pipeline from CONPET. Crude oil spilled in different proportions affected soil until 120 cm.
To detect and characterize the pollution has made profile to a depth of 120 cm of which 5 samples were collected, depending on the sensitive aspect of the sampling surface, 0-20 cm, 20-40 cm, 55-75 cm, 75-95 cm and 100-120 cm.
The polluted profile was classified as epicalcaric chernozem according to the Romanian System of Soil Taxonomy [2].
The analysis achieved using the ICPA methodology were: granulometric fractions, soil reaction by potentiometric method, organic carbon content by titrimetric method of Walkley Black, total nitrogen content by Kjeldahl method, C/N ratio by calculation, mobile phosphorus content by Egner-Riehm-Domingo method, mobile potassium content by flamephotometer method, total petroleum hidrocarbons by gravimetric method and soluble salt content by conductometric method according to the methodologies [8, 9] .

Polluted profile - description

To characterize the profile it will be mentioned only the changes caused by the presence of crude oil on the morphology of profile achieved in the polluted area Perisoru, Braila County.

Epicalcic chernozem polluted with crude oil

polluted Am horizon

0-1 cm crust on the soil surface due to asphaltene which prevents air and water exchange between soil and atmosphere.
intense black 10YR 2/1 on the surface with a whitish tinge caused by the evaporation of water loaded with salts, structure destroyed, massive, hard caused by asphaltene, waterproof wet drops of oil in the horizon base.

1-5 cm very dark brown black 10YR 2/2 - 2/1 structure destroyed, massive, semi-hard, slightly brittle, wet, oil spills on the fracture.

5-15 cm very dark brown 10YR 2/2, semi-destroyed structure with traces of the original structure, granular, wet, oil moistened, leaking through cracks.

15-40 cm very dark brown 10YR 2/2, semi-destroyed structure while maintaining the original structure of some fragments from the initial structure of Am horizon, oil moistened.

polluted Ac horizon

40-55 cm very dark grayish brown 10YR 3/2, the faces of aggregates formed after a weak bleach pollution along the cracks as a result of the salt, partially destroyed and modified structure from massive to subangular polyhedral large, sometimes poorly developed structure granular, sometimes wet and dry over cracks, leaks of crude oil cracks.

55-75 cm very dark grayish brown 10YR 3/2, with weak polyhedral subangular medium grained, crude oil only through the cracks.

75-95 cm dark brown - brown 10YR 3/3 - 4/3, polyhedral subangular to medium grained, moderately developed, sometimes traces of dry or semi-humid oil, white salt stains low frequencies.

polluted Cca horizon

100-120 cm Brown - dark brown 10YR 4/3 - 5/3, white patches of salt with low frequencies, traces of dry oil.

3. RESULTS AND DISCUSSIONS

Physical and chemical characteristics of soil samples from the studied area are presented in following figures.

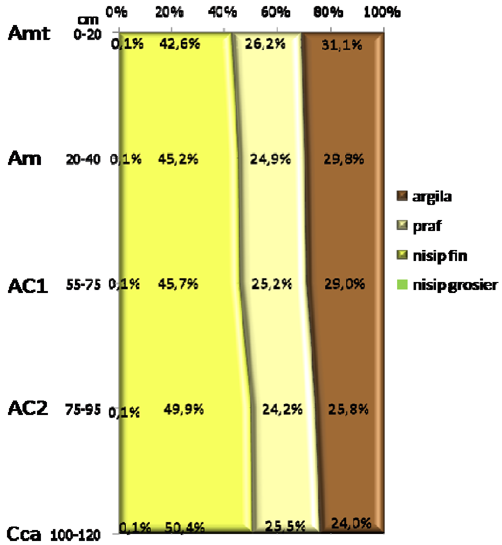

Figure 1 Granulometric fraction determined in the polluted profile achieved in Perisoru, Braila County

Figure 1 shows the granulometric fractions determined in samples collected from the profile achieved at Perisoru. Coarse sand registered the same value 0.1% in all depths. Fine sand shows values between 42.6% and 50.4% increasing with depth. Dust is found more in the surface horizon with a value of 26.2% and the lowest value recorded in Ac_1 horizon, 55-75 cm, had a value of 24.2%. Clay has the highest value in the horizon of the C_{Ca} profile - 34% and the lowest in the Ac_1 horizon - 25.8%. Compared with unpolluted soil chernozem, the values of each fraction is similar with the results obtained in the polluted soil. The granulometric fractions are not influenced by the presence of crude oil.

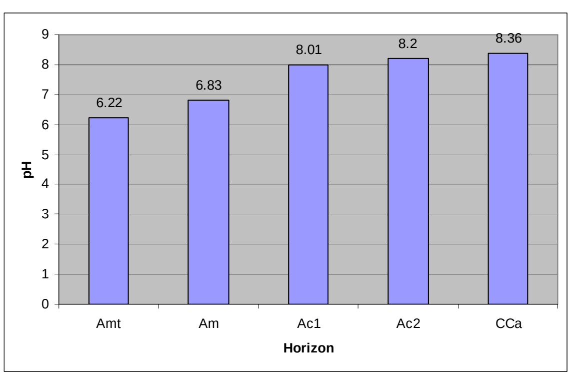

Figure 2 Evolution of soil reaction in the polluted profile achieved in Perisoru, Braila County

Evolution of soil reaction on depth is shown in Figure 2. In the profile achieved in the area with historical pollution Perisoru, Braila County was registered a soil reaction by 6.22 in the surface Amt horizon (0-20 cm) indicating a weak acid soil, a value which increases with depth yielding thus a neutral value of 6.83 in the Am horizon (20-40 cm), reaching values slightly alkaline with depth. Weak alkaline values recorded were 8.01 in Ac_1 horizon (55-75 cm); 8.20 in Ac_2 horizon (75-95 cm) and 8.36 in C_{Ca} horizon (100-120 cm). Soil reaction increases with depth, from a weak acid soil (surface) and goes to a weak alkaline soil starting with 55 cm.

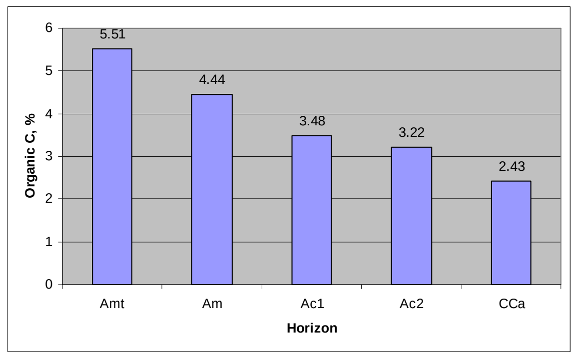

Figure 3 Evolution of organic carbon in the polluted profile achieved in Perisoru, Braila County

The figure 3 presents the evolution of organic carbon in the polluted profile achieved in Perisoru, Braila County. In the polluted profile, high content of organic carbon is observed from the surface to 120 cm. If an unpolluted soil contain organic carbon from 2.23% to 2.02% in the first horizons 0-20 cm and 20-40 cm depth, the values obtained in the polluted profile are much higher, being registered contents by 5.51%, respectively, 4.44%. Also, organic carbon contents decrease with depth reaching a value by 2.43% which indicates that oil pollution has come down to that depth. Normally at this depth, organic carbon content in an unpolluted soil would vary between 0.3-0.5% being extremely low.

Crude oil has a significantly influence on this parameter, the values determined being much higher because of the presence of pollutant.

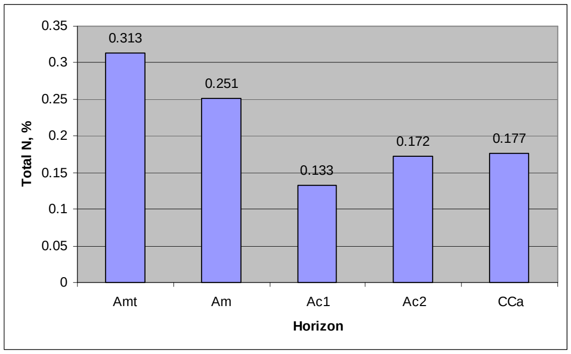

Figure 4 Evolution of total nitrogen in the polluted profile achieved in Perisoru, Braila County

Evolution of total nitrogen in the polluted profile achieved in Perisoru, Braila County is presented in figure 4. In the horizon Amt at 0-20 cm depth, the total nitrogen content registered had a value by 0.313% which indicates a large content, a value that decreases with depth to 75 cm where there is a small content in total nitrogen. In the Am horizon (20-40 cm) was registered a value of 0.251% in total nitrogen content, which indicates a middle content, and then decreases at Ac_1 horizon (55-75 cm) where it reaches a value of 0.133% which indicates a low total nitrogen content of soil. In Ac_2 horizon (75-95 cm) and C_{Ca} horizon (100-120 cm) were determined by total nitrogen content medium having values by 0.172% and 0.177%.

Comparing use an unpolluted soil, the total nitrogen contents are similar with the one determined in the polluted soil.

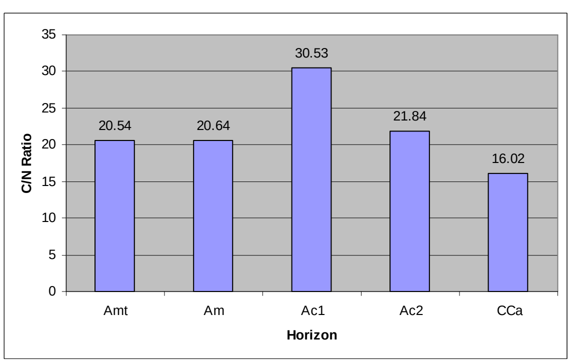

Figure 5 Evolution of C/N ratio in the polluted profile achieved in Perisoru, Braila County

The C/N ratios have the same behavior as organic carbon content. If an unpolluted soil chernozem has a C/N ratio ranges between 13.01 and 12.88 in the 0-20 cm and 20-40 cm depth, in the polluted profile the values for C/N ratios are much higher ranging between 20.54-20.64. The maximum value was registered in 55-75 cm depth where it reaches a value of 30.53 and started to decrease with depth, being registered a value of 21.84 at 75-95 cm depth and a value of 16.02 at 100-120 cm depth.

It also other, C/N decreases with depth reaching 16.02%, which indicates that oil pollution has come down to that depth. Normally at this depth, the C/N has values ranging from 10 to 11 indicating a small content.

Moreover, total petroleum hydrocarbon content will certify the values of C/N ratio and the organic carbon content increased highly comparatively with unpolluted soil because of loading with pollutants.

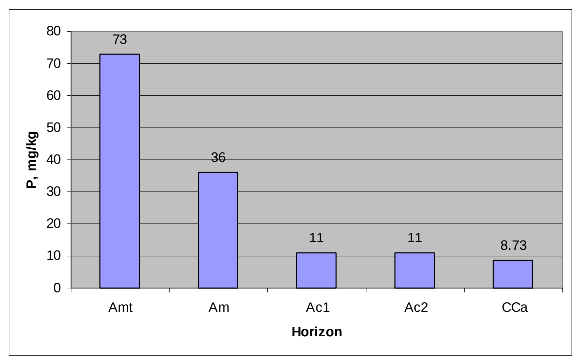

Figure 6 Evolution of mobile phosphorous in the polluted profile achieved in Perisoru, Braila County

As can be seen in Figure 6, mobile phosphorus content decreases with depth, reaching a maximum value at the surface. In the second horizon, the mobile phosphorous decreases by half, over the next three horizons is constant value representing only 1/7 of the value registered on the surface. Thus, in Amt horizon (0-20 cm) of profile was determined a value by 73 mg kg^{-1} which indicates a high content of mobile phosphorus on the surface. The value registered at the surface drops to half in the Am horizon located on 20-40 cm depth having a value by 36 mg kg^{-1} which indicates middle mobile phosphorus content. In the Ac_1 horizon

(55-75 cm), in the Ac_2 horizon (75-95 cm) and in the C_{Ca} horizon (100-120 cm) was determined lower content of mobile phosphorus values by 11 mg kg^{-1}, 11 mg kg^{-1}, respectively 8.73 mg kg^{-1}.

Compared to the contents of mobile phosphorus recorded in an unpolluted soil, the values in the study area are higher, but not significantly because some doses distributed CONPET which content phosphorus and other absorbent materials to remedy the situation.

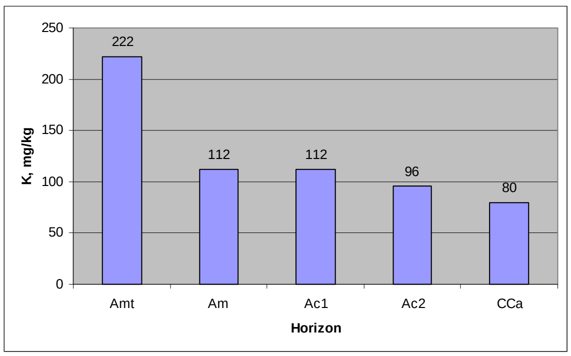

Figure 7 Evolution of mobile potassium in the polluted profile achieved in Perisoru, Braila County

Evolution of mobile potassium in the polluted profile achieved in Perisoru, Braila County is presented in figure 7. Mobile potassium content decreases with depth, having a maximum value at the surface, decreases by half in the other four horizons. Thus, Amt horizon at 0-20 cm depth was determined a value of 222 mg kg^{-1} which indicates a high content of mobile potassium on the surface. The values recorded in the Am horizon located at a depth of 20-40 cm and Ac_1 horizon at 55-75 cm falls within the middle class having a value by 112 mg kg^{-1} in both horizons. In the Ac_2 horizon (75-95 cm) and C_{Ca} horizon (100-120 cm) were determined low potassium content being registered a value by 96 mg kg^{-1} and 80 mg kg^{-1}.

In case of potassium, the situation is similar with phosphorous, so compared to the contents of mobile potassium recorded in an unpolluted soil, the values in the study area are higher, but not significantly because some doses distributed CONPET which content potassium and other absorbent materials to remedy the situation.

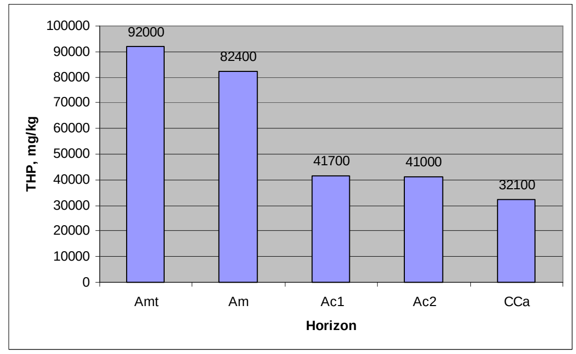

Figure 8 Evolution of total petroleum hydrocarbons in the polluted profile achieved in Perisoru, Braila County

Evolution of total petroleum hydrocarbon content with horizon in the profile achieved at Perisoru, Braila County is shown in figure 8. In the profile achieved in Perisoru area, Braila County was registered a very strong pollution with petroleum hydrocarbons, a descending pollution. In Amt horizon, 0-20 cm was registered a concentration of total petroleum hydrocarbons by 92000 mg kg^{-1}, in Am horizon at 20-40 cm depth, the concentration has a value of 82400 mg kg^{-1}. In the Ac_1 horizon located at a depth of 55-75 cm there is a halving of residual oil content in determining the value of 41700 mg kg^{-1}, almost identical to that of Ac_2 horizon located at 75-95 cm depth, with a value of 41000 mg kg^{-1}. At 100-120 cm depth was identified last horizon (C_{Ca}) of the profile and value of total petroleum hydrocarbons content in continued to decrease reaching the value of 32100 mg kg^{-1}, which maintains the level of excessive pollution.

In the profile developed in the Perisoru, Braila County can be observed a weak salinization at depth between 75 and 120 cm (figure 9). The total soluble salt content increases with depth. Thus, in Amt horizon, (0-20 cm) was recorded a total soluble salt content of 9 mg/100 g soil, in the Am horizon, 20-40 cm, had a value of 15 mg/100 g soil and in the Ac_1 horizon located at a depth of 55-75 cm had a value of 46 mg/100 g soil. In the Ac_2 horizon (75-95 cm) was registered a value of 212 mg/100 g soil, and at

100-120 cm depth (C_{Ca} horizon) value of 146 mg/100 g soil, which shows a weak soil salinization.

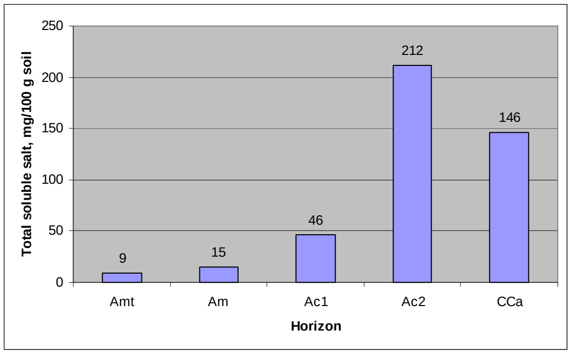

Figure 9 Evolution of total soluble salt in the polluted profile achieved in Perisoru, Braila County

4. CONCLUSIONS

Results of physical and chemical analysis effectuated at the polluted soil samples from polluted profile show large differences compared to the results from an unpolluted soil profile as a result of crude oil pollution in the territory.

The most affected characteristics are total petroleum hydrocarbons, organic carbon content, C/N ratio and soluble salt content.

The pollution degree of the studied area is excessive in the majority of the soil samples.

The highest concentrations are at surface, decreasing with depth. The pollution degree being high has an obviously effect on plant growth.

5. ACKNOWLEDGMENTS

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6. REFERENCES

[1] Engelking, P., Pollution, Microsoft Encarta Online Encyclopedia, 2000.

[2] Florea, N., Munteanu, I., Sistemul Român de Taxonomie a Solurilor, Editura Estfalia, București, 2003.

[3] Gâștescu, P., Gruescu, S.I., 1973 - Judetul Brăila, Editura Academiei R.S.R., Bucuresti.

[4] Odewumi, A., Oil Pollution in Nigeria, A Report on Environmental Pollution Shell Pet. Dev. Co. Warri, 1987.

[5] Odu, C. T. I.: 1977, Microbiology of soils contaminated with petroleum hydrocarbons Natural rehabilitation and reclamation of soil affected, Inst. Petroleum Technol., 1977; Publ. 1, 77–105.

[6] Pepper, I.L., Gerba, C.P., Brusseau, M.L., Pollution Science, Academic Press, 1996.

[7] Toti M., Dumitru, M., Căpitanu, V., Maria Dracea, Carolina Constantin, Constantin Crăciun, 1999 - Poluarea cu petrol şi apă sărată a solurilor din România, Ed. RISOPRINT, Cluj-Napoca, 254 pag.

[8] *** Metode de analiza chimica a solului, Bucuresti, 1986.

[9] *** Metodologia elaborarii studiilor pedologice, vol. III, Indicatorii ecopedologici, Bucuresti, 1981.