GEOLOGICAL FACTORS CONTROLLING THE S0IL AND SHALLOW AQUIFER OIL CONTAMINATION. APLICATION TO A LARGE OIL STORING FACILITY ON THE ROMANIAN BLACK SEA COAST

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Abstract: The subsurface geological investigation of the Oil Terminal South area (Constanța, Romania) pointed out that the hydrocarbon contamination of the shallow aquifer is largely governed by the phreatic water flow pattern. In turn, the water flow is controlled by the Lower Pleistocene paleo-relief, which determines the existence of two main water flow directions. Due to the narrow grain size range, the lithology does not act as a governing factor of the oil contamination.

Key words: oil contamination, shallow aquifer, paleo-relief, lithology.

1. INTRODUCTION

The major requirement, ensuring the trustworthiness of an environmental remediation project, is the necessity of placing the deep understanding of the pollution situation at the base of the risk assessment, monitoring and remediation actions. The full comprehension of the hydrocarbons contamination processes and the correct identification of the factors governing the mechanism of these processes is essential within this context.

The investigation presented in this paper was carried out within the perimeter of the Oil Terminal South oil storing site (Constanța, Romania) (Fig.1), one of the largest facility of this kind in Eastern Europe. Although Oil Terminal South is the youngest oil storing site in Constanța (only about three decades of activity), oil contamination of soil and shallow aquifer is rather advanced.

Numerous wells have been drilled in the Oil Terminal South area in the years 1995 and 2000. The information provided by the wells drilled within the perimeter of Oil Terminal South storing facility pointed out that the oil contaminated Quaternary deposits display the following dominant lithologic sequence (Fig. 2):

- upper loessoid horizon, consisting mainly of loess (silt with 20-30% clay), the coarser grained Quaternary deposits;
- middle paleosol horizon, characterized by the dominance of the silty clay sediments; through outcrop investigations Conea (1970) separated several paleosoil groups in a section with a geometrical position similar to our middle horizon;
- lower, red clay horizon.

HYDROCARBON CONTAMINATION STATUS OF THE OIL TERMINAL SOUTH AREA

Soil/sediment hydrocarbon contamination. The investigation of the wells data (Jipa et al., 2001) pointed out that in the Quaternary sedimentary column there are intervals contaminated with petroleum products.

Most of the time only one contaminated interval occurs in the sedimentary column of the investigation wells (Fig. 3A). Two or even three contaminated intervals have been also observed.

A large thickness range (0.4 to 10.1 m) is characteristic for the contaminated intervals outlined in the Oil Terminal South area (Fig. 3B). The most frequent thickness values of the oil polluted sediment intervals vary between 1 and 3 m.

The contaminated intervals occur at various levels within the Quaternary sediments, from 0 m depth (soil surface) to 9.5 m depth (Fig. 3C).

All lithologic types of sediments drilled in the investigation area are affected by the hydrocarbons contamination (Fig. 3D).

Ground water hydrocarbon contamination in Oil Terminal South area

*Free phase contaminating petroleum products floating on the shallow aquifer***.** Using a specially designed device (Opreanu, Dan, 2001), measurements have been performed in wells in order to determine the thickness of the free petroleum products accumulated on the surface of the phreatic aquifer

Out of 16 measurement points covering the whole petroleum products storing facility area (Fig. 4) in twelve points the free phase hydrocarbons occur as a thin coating. Measurements conducted in the remaining 4 wells (located in the eastern and northeastern sector of the investigated area) pointed out the presence of free phase hydrocarbons making up layers of 2 to 32 cm thickness.

*Contaminating hydrocarbons dissolved in the shallow aquifer***.** Fluorescence intensity data (Popescu et al., 2001)indicated relatively high dissolved hydrocarbon contents in 24% of the 30 analyzed water samples, collected from the upper part of the phreatic aquifer. The highest content values occur into the northeastern sector, which also includes the thickest accumulations of floating oil. More restricted sectors with high content dissolved hydrocarbon have been outlined in the southwestern and southeastern parts of the investigated area.

Geological/hydrogeological factors controlling the oil contamination processes.

Lithology. As stated in a previous chapter (Fig.3D), the hydrocarbon contamination process is affecting all Quaternary lithofacies (including the red clay); not showing a privileged relationship with a certain level of the lithologic section.

The unusual lack of implication of the lithologic control is due to the narrow grain size range of the Quaternary deposits, extending mostly in between clayey silt and silty clay varieties. Even the red clay deposits include high amount (up to 45%) of silt particles.

*Dynamics of the shallow aquifer***.** Hydrodynamic models for the 1995 and 2001 years conditions have been realized (Dinu et al., 2001) (Fig. 5) for the shallow aquifer in the area of the Oil Terminal South storing facility. The upper surface of the shallow aquifer in the investigated area appears tilted, with a dominant southern slope. The prevailing southern water flow direction is accompanied by a secondary eastern flow direction.

The major flow directions of the shallow aquifer indicated by the hydrodynamic model explain very well the occurrence of different sectors with high contamination values (Fig. 6).

*Pre-Quaternary relief***.** Although partly affected by oil contamination, the red clay section of the studied sedimentary sequence makes up the impermeable base of the shallow aquifer. The structural-morphologic contour map prepared for the upper red clay surface (Fig. 7) points out significant relief variations. At large scale the paleo-relief is expressed by a surface with a definite southern gradient.

Due to the southern tilting paleo-slope above discussed, the Quaternary sediments drilled in the Oil Terminal South area shows a southern dipping and their thickness increases toward the south. These variations determine the main structural geological features of the investigated sediments. Following the paleo-relief,southern gradient the water table of the shallow aquifer is also inclined.

The major south sloping surface of the paleo-relief in the investigated area shows a well-expressed medium scale morphologic feature, consisting of a north to south elongated ridge. There is a striking similitude between the paleo-morphology contour map and the piezometric contour map of the aquifer (Fig. 5). It is therefore reasonable to believe that the presence of the ridge produced a flow separation within the shallow aquifer (Fig. 7). Most of the aquifer followed the morphologic depressional area west of the paleo-ridge. The eastern slope of the ridge is the paleo-morphologic element that generated a lateral, eastern component of the shallow aquifer water flow. Consequently, part of the contaminating oil products reaching the shallow aquifer has been driven eastward, with important consequences for the environmental situation.

CONCLUSIONS

The subsurface geological investigation of the Oil Terminal South area (Constanța, Romania) pointed out that the hydrocarbon contamination of the shallow aquifer is largely governed by the phreatic water flow pattern. In turn, the water flow is controlled by the Lower Pleistocene paleo-relief (top of the red clay horizon), which determines the existence of two main water flow directions.

The understanding of the contamination process dynamics provides a solid ground for the risk assessment, monitoring and remediation actions in the investigated oil storing facility area.

References

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Fig. 1. Location of the investigated Oil Terminal South area, Constanța (Romania).

Fig. 2. Lithologic sequence of the Quaternary deposits investigated in Oil Terminal South area, Constanța (Romania).

Legend: a-modern soil; b-loess (silt with 20-30% clay); c-paleosoil (silt with 30-40% clay); d-red clay.

Fig. 3. Characters of oil contaminated soil/sediments in Oil Terminal South area, Constanța (Romania).

A. Number of oil contaminated intervals observed in the drilling column.

B. Extreme thickness values of the hydrocarbon contaminated intervals.

C. Range of depth occurrence of the contaminated intervals. D. Lithology-contamination relationship.

Legend: a-modern soil; b-loess (silt with 20-30% clay); c-paleosoil (silt with 30-40% clay); d-red clay; e-contamination interval.

Fig. 4. Thickness of free phase petroleum products accumulated on the shallow aquifer. Oil terminal South storing facility, Constanta.

Legend: a- well location. b- thickness of oil product floating on the aquifer upper surface. c- oil film coating the aquifer upper surface. d- area of important floating oil accumulation.

Fig. 5. Flow directions in the shallow aquifer of the Oil terminal South storing facility, Constanta.

Legend: a-local flow direction; b- well location; c-piezometric contour lines; d-water table elevation values (m); f-study area perimeter.

Fig.6. Major flow direction of the shallow aquifer in relation with the high contamination sectors.

Legend: a-sector with significant free phase hydrocarbons floating on the shallow aquifer; b-sectors with significant dissolved hydrocarbons in the shallow aquifer; c- major flow direction of the shallow aquifer.

Fig.7. Morphological map of the red clay upper boundary surface.

Legend: a-contour line; b-elevation in meters; c-major flow directions of the aquifer; d-morphologic ridge


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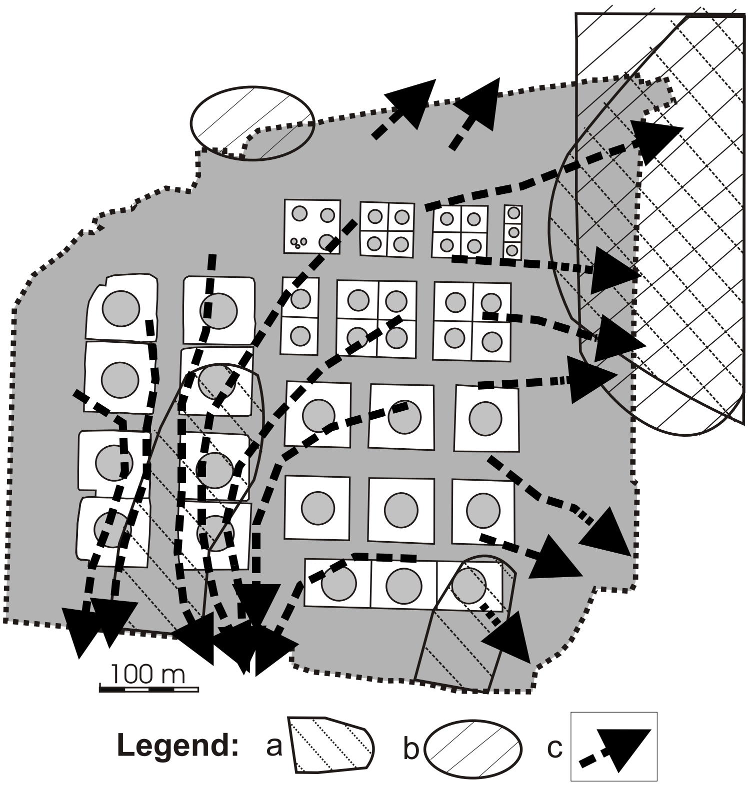
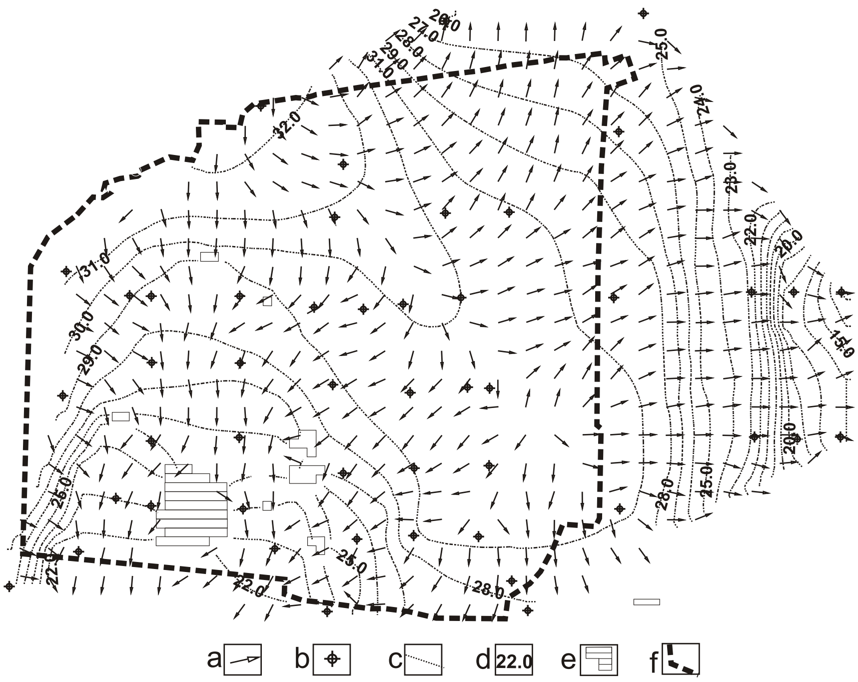
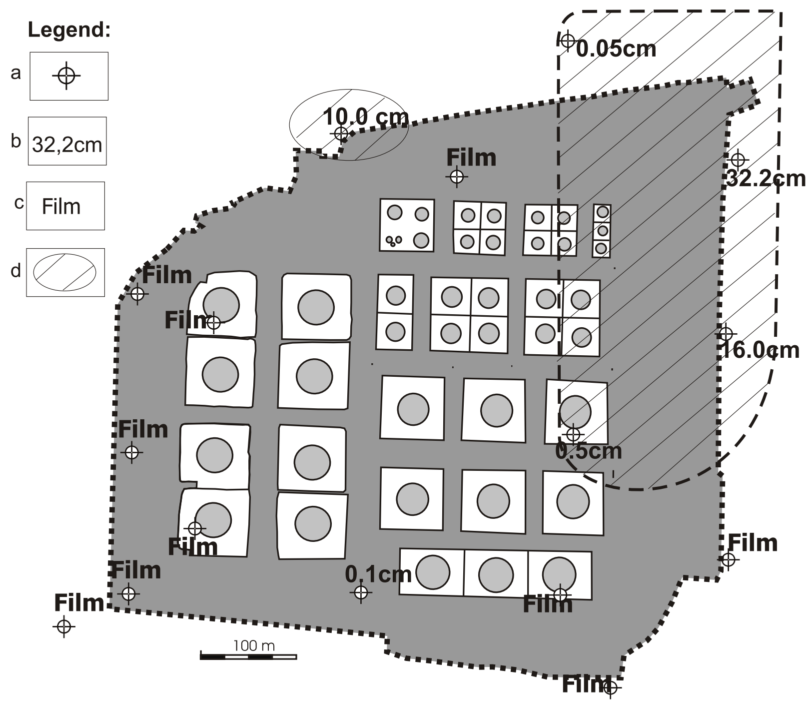

100 m
Legend:
a
b
c



a
b
c
d 22.0
e
f



Legend:
a
b
32,2cm
c
Film
d
0.05cm
10.0 cm
Film
32.2cm
Film
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Film
Film
0,1cm
Film
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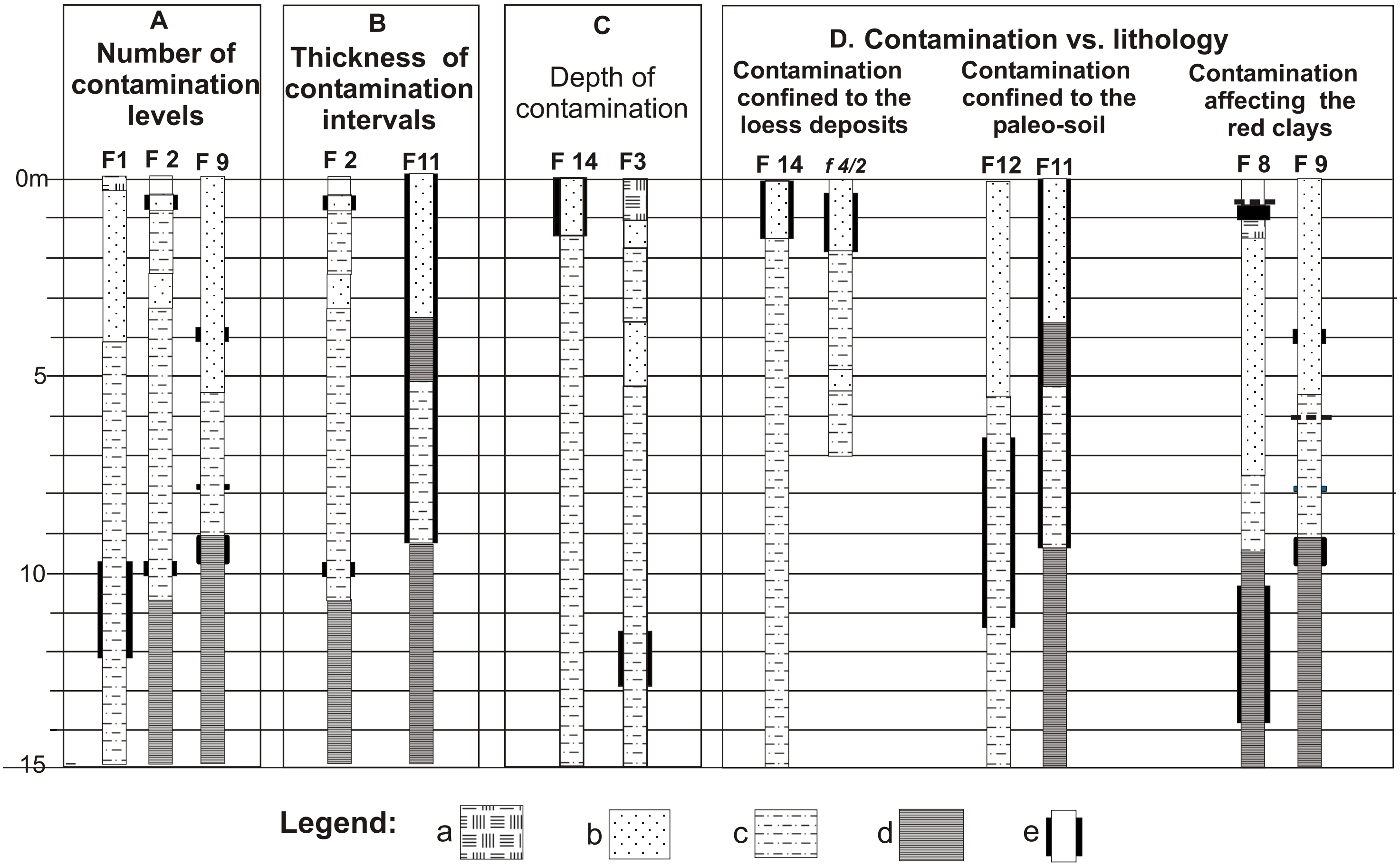
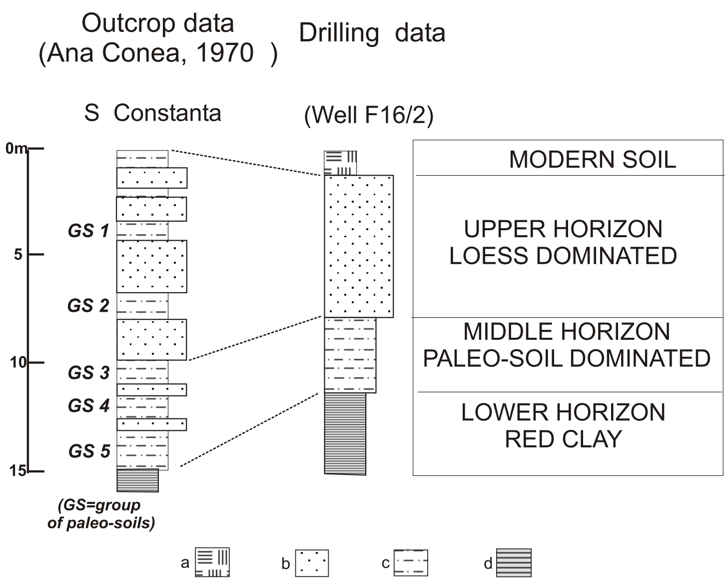
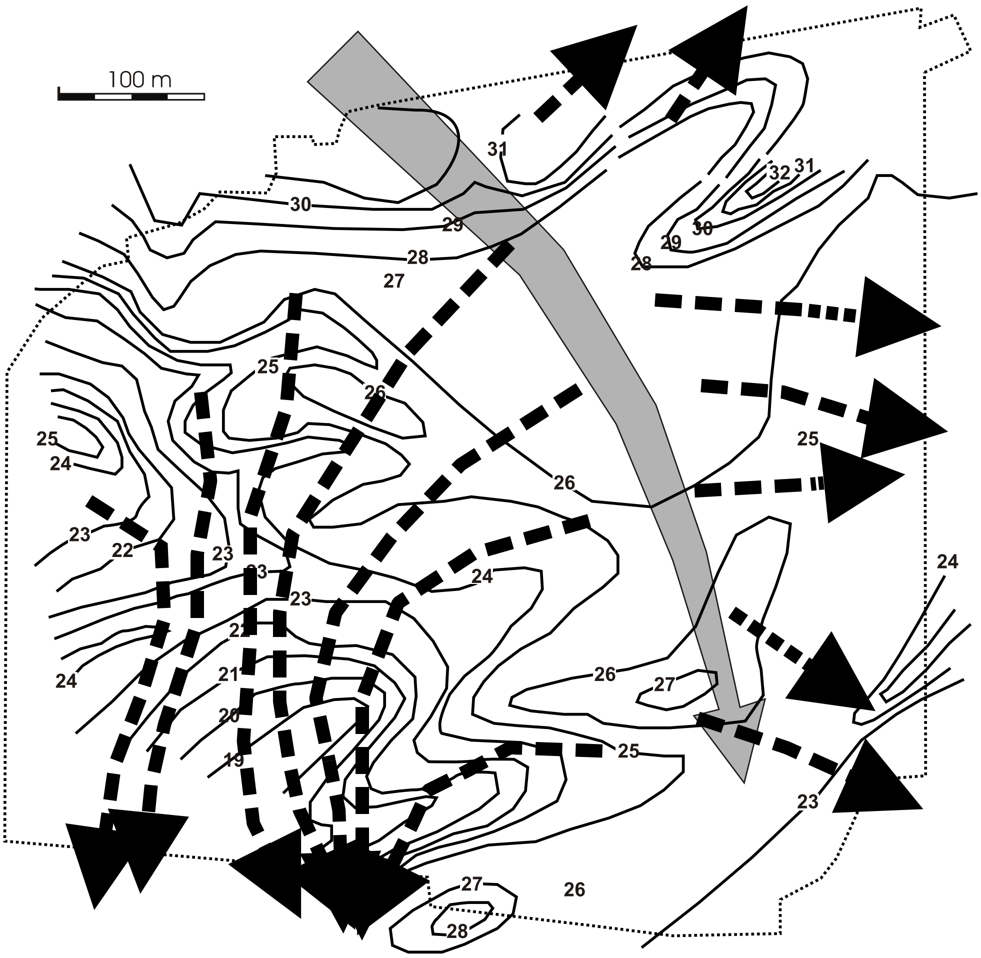
100 m
Film



A
Number of contamination levels
B
Thickness of contamination intervals
C
Depth of contamination
D. Contamination vs. lithology
Contamination confined to the loess deposits
Contamination confined to the paleo-soil
Contamination affecting the red clays
F1
F 2
F 9
F 2
F11
F 14
F3
F 14
f 4/2
F12
F11
F 8
F 9
0m
5
10
15
Legend:
a
b
c
d
e


Outcrop data
(Ana Conea, 1970)
Drilling data
S Constanta
(Well F16/2)
0m
5
10
15
GS 1
GS 2
GS 3
GS 4
GS 5
(GS=group of paleo-soils)
MODERN SOIL
UPPER HORIZON LOESS DOMINATED
MIDDLE HORIZON PALEO-SOIL DOMINATED
LOWER HORIZON RED CLAY
a
b
c
d



Legend: a b 19 c d