Scientific Papers. Series E. Land Reclamation, Earth Observation & Surveying, Environmental Engineering. Vol. IX, 2020
Print ISSN 2285-6064, CD-ROM ISSN 2285-6072, Online ISSN 2393-5138, ISSN-L 2285-6064

PARTICULARITIES OF THE ASSESSMENT OF LAND AND GROUNDWATER CONTAMINATION IN THE AREA OF PETROLEUM PRODUCT WAREHOUSES

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Abstract

The study presents the main investigation and assessment methods of quantifying the level of contamination of potentially contaminated and contaminated sites, the advantages and limitations dictated by the specificity of petroleum product storage and distribution sites (warehouses) and also by the type of information required for their optimal characterization. Case studies and real contaminated sites are used in this analysis to be more applicative and convincing for the scope of this assessment. The conclusions of this analysis allow establishing the mechanisms and particularities of soil and groundwater pollution on petrochemical industrial areas, as well as the petroleum product deposits in terms of geological and hydrogeological characteristics, pollution sources, and activities conducted on these platforms. The study is a preliminary stage for the assessment of the risk generated by the level of contamination with such products. This study will ensure a very useful and effective tool for establishing the protection and remedial measures for this type of soil and groundwater contamination.

Key words: *contaminated site, deposits, investigation methods, petroleum products.*

INTRODUCTION

The development of the oil industry in Romania over time was, to a small extent, associated with the environmental protection issues. The extraction, processing and transport of petroleum products have been conducted at a swift pace and without paying major attention to the environment. During the Second World War, many sites of this industry were bombing targets, thus causing pollution of the underground environment. These situations have led, over time, to a significant pollution, accumulated and extended, of the underground environment.

The administrative framework regarding the management of contaminated sites has identified 1393 potentially contaminated site sand contaminated sites (mainly specific to the mining industry, metallurgical industry, oil industry, and chemical industry).

A recent update of the registry, in 2017, listed 516 contaminated sites for the oil and gas industry. The limitation and/or elimination of the potential risks to the human health and to the environment can be achieved by reducing the impact on the environment, caused by soil and underground water contamination. To take these measures, an investigation is necessary, during the first stage, so as to widely and rigorously get familiarized with the site, assess the contamination, and decide the next steps to be taken.

The case study has the particularities of a storage and distribution site (warehouse) for petroleum products, a specific one, considering most of the geological and hydrogeological characteristics, the activity carried out, the general and particular components (Bica, 1998). The main scope of business is the supply, through railway and road transportation means, the storage in vertical and horizontal, over ground and underground tanks. To make sure the entire activity is carried out, the site included the main facilities: loading/unloading platform to ensure the transfer of products, storage tanks, pumping station, settling tank, separating tank, over ground and underground transmission lines, urban public networks, product storage premises, concrete platform, administrative buildings, green areas.

The potential causes of pollution during the activity carried out in warehouses have been split into three categories (Figure1):

- **technical causes:** leaks along the underground or over ground technological pipes through the joints and cracks of pipe sections, of armatures; deterioration of transmission lines over time, first because of the chemistry of circulated water; leaks of petroleum products from the storage tanks when filled or when in stand-by; leaks of petroleum products during the supply from the vehicle platform; joints in the tanker unloading railway platform area; malfunctions of the technological platforms that could cause leaks of petroleum products as a result of the failure to conduct revisions and repairs in due time or accurately; the lack of a potential leaks retaining system or its deterioration;
- **human causes:** handling of petroleum products, loading/unloading of petroleum products; emptying and cleaning of the tanks and of the petroleum product storage technological platforms; during the decommissioning or demolition of technological platforms and pipes;
- **natural causes:** the nature of the underground environment can favour the contamination and transport of pollutants because of the lithological composition and hydrological characteristics.

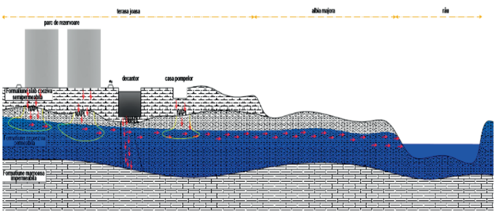

Figure 1. Petroleum product deposits-main causes of contamination of the underground environment

Usually, the lithology of deposits is characteristic to river plain areas (major bed), terraces, as well as to plain and plateau areas. The upper soil layer is slightly cohesive (clayey sand, silty sand, sandy silt), followed by a non-cohesive layer (sand, gravel).

The underground water level is high, allowing the quick infiltration and migration of the pollutant in the underground water flowing direction, even off the site limits. From the geomorphological point of view, the analysed site is located in a terrace area, close to its contact with a plain area (Figure 2). The land has a slight downgrade that descends from west to east (from the elevation of 100 maBS to 97.50 maBS), then follows an embankment approx. 7.0 m high, connecting to the plain area. In this area, the land slope is much gentler, from the elevation of 90 maBS to 89 maBS.

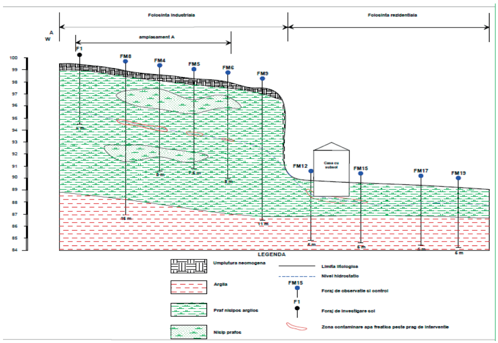

Figure 2. Lithological section

The terrace area consists, at the surface of the land, of an infilling layer approx. 0.50 m thickness, under which a semi-cohesive formation develops, mainly consisting of sandy silthat meet clayey sand lentils. This formation is quite thick, approx. 10 m. The bedrock formation develops under this layer, impermeable, consisting of marly clays. In the plain area, at the surface of the land, a vegetal soil layer develops, under which the semi-cohesive formation appears, mainly consisting of sandy silt approx. 2.50 m thickness. The bedrock formation develops under this layer, consisting of marly clay.

From the hydrogeological point of view, the presence of a free-flowing phreatic aquifer is noticed, surrounded by semi-cohesive formations. In the terrace area, the underground water level goes approx. 4.50 m deep, whereas in plain areas, approx. 1.60 m deep. The phreatic aquifer is supplied particularly from rainfall. During intense rainfall periods, springs are noticed at the bottom of the embankment of terrace a. The general flow direction of the phreatic aquifer is from west to east.

MATERIALS AND METHODS

The work method applied for this study includes a characterization of the polluted site, the application of the investigation methodology, and the identification of the soil and underground water sampling points, the use of direct, preliminary and detailed, investigation methods by sampling undisturbed soil samples and analysing them in the laboratory (ANZECC, 1999; Fetter, 1993). The organic pollutants identified and analysed were: aliphatic hydrocarbons (TPH Total Petroleum Hydrocarbons), aromatic hydrocarbons BTEX (benzene, toluene, ethylbenzene, xylene), MTBE, heavy metals (copper, lead, sulphur). The negative impact is caused by the concentrations of pollutants that exceed the regulations of the legislation in force and may pose a risk to the site recipients.

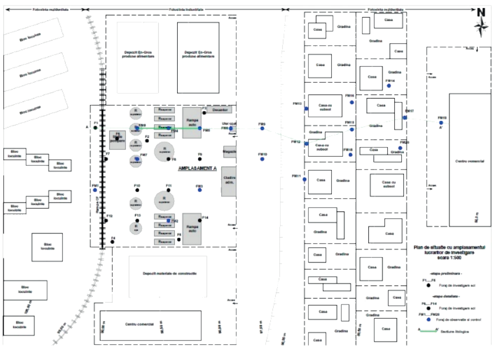

Figure 3. Master plan of the warehouse, with location of technological items

After analysing the available information, a preliminary soil and subsoil investigation plan was prepared, at site level, taking into account the potential sources of pollution and the clearly contaminated areas.

The judgment-based investigation method was used. The benefits of this investigation method, which is the most common method, are that it requires low costs and identifies the site contamination based on the available data. The main limitation of the method is given by the fact that the contamination cannot be validated and that it could allow errors to occur because of its structure (M.E., 2004). Five soil investigation drillings, each 5 m deep, were included.

The soil investigation drillings were located in the area of the potentially polluting and easily accessible constructions (Figure 3). These were located in the area of the railroad (F1, F4), in the area of the tanks located in the northern part of the site (F2), in the settling tank area and vehicle loading platform area (F3), as well as in the south tanks area, vehicle loading platform (F5).

Soil samples were taken from these drillings and one underground water sample from the F3 drilling, analysing the concentrations of TPH, BTEX, heavy metals (copper, iron, sulphur, lead). Direct investigation methods were used, soil investigation drillings were performed mechanically, in dry system. Soil samples were taken from depths of 0.30 m, 1.0 m and then every meter down to an approximate depth of 5.0 m, depending on the contamination identified organoleptically.

The existence of soil pollution, caused by the activity carried out on the site, known in the preliminary investigation stage, and knowing that the downstream underground water is contaminated because of the petroleum product irisations and smell, it was decided to do a detailed investigation both at site level and downstream, in the underground water flowing direction.

The fluctuation of the underground water level between rainy and droughty periods over the year has implications on the vertical migration of the pollutant, particularly of the NAPL type (non-aqueous phase liquids), refined, light petroleum products, that quickly infiltrate (Bica, 2014). The detailed investigation will aim at the vertical and horizontal detailing of the soil, subsoil, and underground water pollution in the entire potentially contaminated and contaminated area, its special delimitation, depending on the depth, nature and intensity of pollution, the connection between pollutants and the structure of the geological environment, the pollution migration and transport paths (Bica, 2014; Manescu, 2002) .

To get more details about the pollution of the soil and underground water, the soil drillings and, subsequently, the observation and control drillings (piezometers) were systematically placed approx. 25 m away from it, both inside and outside the site.

The systematic investigation model will reduce subjectivism, detecting contaminated areas, other than the previously known ones, and can validate the sites in terms of residual contamination (M.E., 2004).

The limitation of this method could be about the high costs and the large number of the investigation points (M.E., 2004). The soil investigation drillings were conducted mechanically with percussion, in dry system. The drilling method was chosen so as not to allow contamination between the various depth ranges and the soil samples taken be as representative as possible.

Drillings were located in the railroad area(FM1, F7, F12, F4), in the northern tanks area (FM8, F2, FM4, FM7, F8, F9), in the vehicle platform area (FM5), in the pumping station area (F3), in the scavenge oil storage area (FM6), in the central area (F10, F11, FM3), in the southern tanks area (F13, FM2), in the southern vehicle platform (F14), between the site and the residential area (FM9, FM10), in the residential area (FM11÷FM20).

Outside the site, the investigation works were conducted in the potentially polluted areas at the soil and underground water level, by also taking into account the characteristics of the pollutant type and the information available during the preliminary data analysis stage. At the same time, the accessibility of the staff and equipment, in view of conducting these works, was taken into account.

RESULTS AND DISCUSSIONS

After analysing the laboratory results and the isolines with TPH concentrations, it follows that the contamination of the soil, particularly at the level of the former facilities: pumping station, tanks and vehicle platform in the northern area of the site, settling tank, specifically the railroad and the scavenge oil storage area. Also, it is estimated that, in this area, the pollutant migrated vertically into the soil, down to the underground water level, contaminating it. The results of the laboratory tests, that took into account the provisions of Order 756/1997 on the assessment of environmental pollution, have shown a significant contamination of the soil with petroleum products intended for less sensitive use (Figure 4).

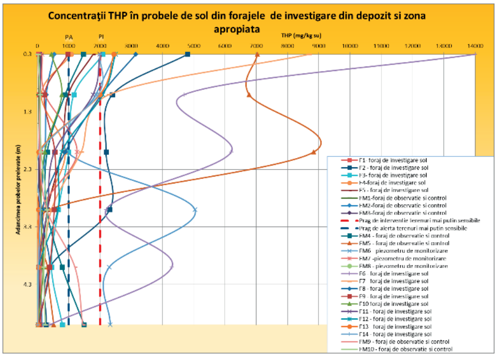

Figure 4. TPH concentrations in the soil samples of the investigation drillings on site and in the adjacent area

The results obtained after performing the investigation works and the laboratory tests were entered into the Surfer software, which modelled the distribution of the TPH contamination of the soil at various depths (above the intervention threshold, 2000 mg/kg, for less sensitive lands), highlighting the following aspects: - for the depth of 0.3 m, inside the site, the TPH contamination was encountered in the area of the former potentially polluting constructions: pumping station (F6), railroad (F7), tanks (F2, F8) and vehicle platform (F3, FM5) in the northern area of the site, in the scavenge oil storage area (FM6) and on a small area near a tank (F12, F13) in the southern part of the site; - for the depth of 1.0 m, the TPH contamination in the pumping station area (F6) and the vehicle platform (FM5) in the northern part of the site; - for the depth of 2.0 m, the TPH contamination in the pumping station area (F6), tanks (F2) and vehicle platform auto (FM5) in the northern part of the site; - for the depth of 3.0 m, the TPH contamination in the scavenge oil storage area (FM6); - for the depth of 4.0 m, the TPH contamination in the pumping station area (F6), tanks (FM8) in the northern part of the site and the scavenge oil storage area (FM6); - for the depth of 5.0 m, the TPH contamination in the scavenge oil storage area (FM6) (Figure 5).

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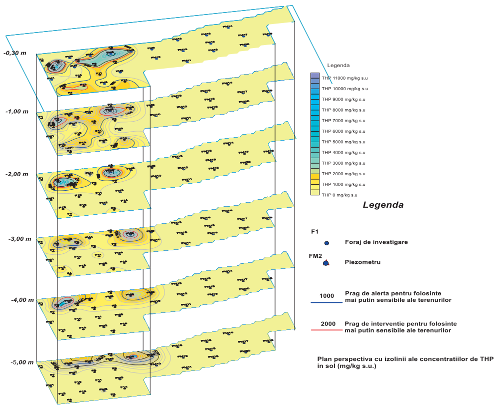

Figure 5. Isolines of contaminated area within the depth range 0.3 m ÷ 5.0 m

The results of the laboratory tests have shown a contamination of the underground water both in the site area and downstream of the site, in the residential area in the underground water flowing direction. The values of Total Petroleum Hydrocarbons in the underground water, above the intervention threshold limit, were identified in the observation and control drillings FM8 and FM4 (the tanks area in the north part of the site), FM5 (vehicle platform), FM6 (scavenge oil storage area) and FM12 in the residential area. The values of Total Petroleum Hydrocarbons in the underground water, between the intervention threshold and the alert threshold, were identified in most observation and control drillings, except for those located in the southern part of the site (FM1, FM2 and FM3), F3, as well as those in the residential area FM14 and FM19.

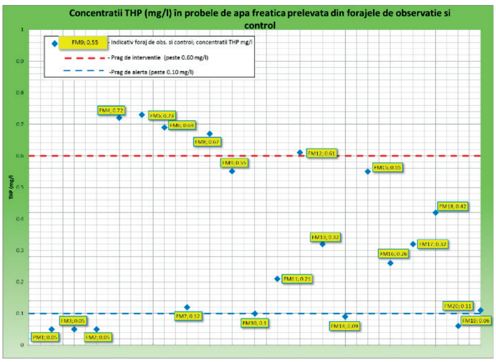

Figure 6. TPH concentrations in the underground water samples taken from observation and control drillings

After analysing the isolines, the TPH concentrations in the underground water show an infiltration of the pollutant from the northern area of the site and its migration in the underground water flowing direction, as well as an extension of the plume up to the residential area in the proximity of the site (Figures 6 and 7).

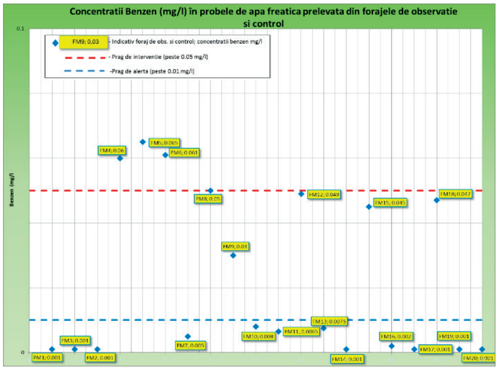

Figure 7. The benzene concentrations in the underground water samples taken from observation and control drillings

CONCLUSIONS

The pollution recorded over time on the petroleum product storage and distribution sites (warehouses) has had a negative impact on the environmental factors: soil, subsoil and underground water. As compared to pits and tank parks, warehouses cover the most extended pollution areas. Another particularity of these is their location inside human settlements, with the built-up area, with a potentially significant impact on the sensitive recipients (residential areas, hospitals, schools, etc). The specific geological characteristics are the plain areas, terraces, and plain and plateau areas, with predominantly slightly cohesive and non-cohesive lands. From the hydrogeological point of view, the underground water level is high, allowing a quick infiltration and migration of the pollutant in the underground water flowing direction. The contamination investigation methods for soil and underground water are mainly direct ones. As far as investigation drillings are concerned, which specific to the case study, they are used without drilling fluid (dry system), with protection tubing, so as to avoid (crossed) pollution between layers and the deep pollution of the soil and underground water. In the case of piezometers, it is recommended that the underground water level permanently fluctuate in the filters section, so as to identify the existence of the free stage of the petroleum product and, potentially, to measure its thickness (NAPLs) and the tubing materials should be environmentally-friendly. The specificity of the site and the type of information taken into account to characterize the warehouses allowed the optimal choice of investigation models by judgment-based and systematic taking and collecting of samples. The pollution of the underground environment of the warehouse was favoured by the migration, transport and dispersion conditions of hydrocarbons. The specific contaminants for the soil environmental factor are TPH, benzene, and in the case of underground water, NAPL contamination was found at some distance from the site, in the residential area (subsoil of constructions) at approximately 10 m. The theoretical assessment of the contaminated areas at the level of the former technological items specific to the warehousing activity could be demonstrated using judgment-based and systematic sampling methods, as well as laboratory test results. The identified and validated *hot spot* areas were the pumping station, the storage tanks, vehicle loading platform, unloading railway platform, scavenge oil storage area. The contamination of the soil and of the underground water is a concern, aiming to improve the quantitative and qualitative risk assessment steps and the contamination of the former petroleum product storage and distribution sites, so that the remedial systems design parameters may be determined.

ACKNOWLEDGEMENTS

This research work was carried out with the support of Technical University of Civil Engineering Bucharest, Department of Hydraulics and Environmental Protection and TUVAustria Romania.

REFERENCES

ANZECC (1999). Guidelines for the assessment of on-site containment of contaminated soil. Australia and New Zeeland Environment and Conservation Council.
Bica, I. (2014). Remedial of Contaminated Sites.
Bica, I. (1998). Pollution of Aquifers. Remedial Techniques.
Fetter, C.W. (1993). Contaminant Hydrogeology.
Manescu, M. (2002). Pollution of Underground Waters. Case Studies.
Ministry for the Environment (M.E.) (2004). Contaminated Land Management Guidelines No.5: Site Investigation and Analysis of Soils.