Analysis of the pollution degree of the geological environment on a petroleum product storage & distribution site

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Abstract. The study presented in this paper was conducted on a site pertaining to the distribution & storage component of the oil industry, the business of which was mainly the supply, using railroad and road transportation means, followed by storage in tanks and trading of petroleum products (e.g. gasoline, diesel oil, various oils). To carry out its activity, the site had the following technological equipment: vehicle loading platform/railway unloading platform, storage tanks, pumping station, hydrocarbon separator, technological transport pipes, storage areas, administrative buildings, etc. Based on the characteristics of industrial sites, a synthesis of the particularities of these site types was made. To that effect, the direct connections in terms of the specificity of the main and auxiliary activity were taken into account, as well as the handled chemicals and raw materials, but also how the waste was managed during the operational processes.

Introduction

Most of the pollution cases in the geological environment are the result of accidental spillage during storage, handling and transport of various materials and chemicals specific to a petrochemical site.

According to the annual environmental reports, the potentially contaminated sites are found essentially in the hydrocarbon extraction sector, in the petroleum product storage sector, and in the mining industry. The soil pollution in Romania, according to the Environmental Report [1], affected 24,432 ha of land as a result of mining, whereas the pollution as a result of the oil extraction, respectively pollution with salty water or associated with mineral oil pollution, affected both the soil and the underground water on an area of 2,654 ha (in the southern region of Muntenia and the southwestern part of Oltenia), while 751 ha of land were affected as a result of the oil transport and processing.

Table 1 The parameters of petroleum products storage and distribution sites in view of clarifying the method and ways of investigation and remediation [2]

| Parameter                  | Description                                                                 |
|----------------------------|-----------------------------------------------------------------------------|
| Size                       | Approximately 2 ÷ 50 ha                                                     |
| Products, raw materials,   | Mineral oil, gasoline, diesel oil, light liquid fuel, scavenge oils, heavy  |
| waste                      | oil, and other stored chemicals                                             |
Potential contamination sources

Mainly punctual or local, linear or spatial (e.g. loading/unloading platforms, tanks, pumping stations); the existence of underground pipe networks will be taken into account (potential unemptied pipes containing chemicals specific to the activity carried out) or buried tanks/pits.

Types of pollutants

TPH (Total Petroleum Hydrocarbons), light volatile hydrocarbons, heavy metals (e.g. lead), PAH (Polycyclic Aromatic Hydrocarbons), additives (e.g. MTBE, ETBE).

Potential contamination causes

Leakage of petroleum products from storage tanks, leaks along the technological pipes or through the pipe joints, fittings in the pumping station, handling of petroleum products, loading/unloading on the road platform or railway platform.

Observations

Frequent location within the built-up area, but also outside the built-up area of human settlements.

It is a facility where the products obtained from the refinery are stored and later delivered to the customer. In some cases, certain additives could also be added to the products stored in tanks (e.g. to increase the octane rating).

The paths of contaminants migrating into the environment are directly connected to the particularities of the geological environment (geological, geomorphological and hydrogeological characteristics).

The lithological layer (Figure 1) of the analysed site describes the fact that, down to the depth of approximately 0.7 m, a non-homogenous filling layer develops, consisting of a clayey-sandy layer mixed with sands and gravels. Under these layers, down to depths of 6.70 - 7.40 m, a slightly cohesive formation develops, consisting of clayey sandy dusts, plastically consistent. Starting from depths ranging between 6.70 - 7.40 m down to depths of 9.30 - 9.60 m, a non-cohesive formation develops, consisting mainly of wet sands, and down to the depth of 10 m a dusty clay layer, plastically hard, is identified.

The phreatic aquifer is surrounded by the non-cohesive formation, consisting of sands (Figure 1). This aquifer is supplied particularly from rainfall and from the nearby river.

![Figure 1. Lithological section showing the contaminated areas in the geological environment](image)
Method and methodology
The understanding of the physical and chemical properties of contaminants has determined the investigation methodology in terms of establishing the sampling points, collecting the samples, and establishing the methods to measure them. Also, these properties control the transport of pollutants into the underground environment, determining the size of the polluted area. As regards the types of pollutants specific to the distribution and storage oil industry, it is important to know and assess the characteristics of chemicals, such as: water solubility, density, boiling point, steam pressure, volatilization of pollutants, biodegradability [2].

To assess the degree of horizontal and vertical contamination of the site, 20 soil/subsoil investigation drillings were conducted, out of which 5 drillings (FYP1, FYP2, FYP3, FYP4, FYP5) were turned into hydro-observation drillings to assess the ground water quality evolution in time (Figure 2). The drillings were placed in such a way as to cover the entire site, but mainly focalised on the potential pollution sources (judgmental and systematic sampling designs) [3].

Results
The results obtained after conducting the investigation works and the laboratory tests were compared to the intervention thresholds for less sensitive lands for various depths, retaining the following aspects (Figures 3 ÷ 6):

- at the depth of 0.30 m: contamination with TPH in the area of the former buildings with great polluting potential: pumping station (FY6), railway platform (FY18, FYP4), tanks (FY20, FY18, FYP5) and vehicle platform (FY14) in the northern part of the site, the scavenge oil storage area and on a small area near a tank in the southern part (FY12);
- at the depth of 1.00 m: contamination with TPH at the pumping station (FY6) and the vehicle platform (FY14) in the northern part of the site;
- at the depth of 2.00 m: contamination with TPH in the pumping station area (FY6), tanks (FY20) and vehicle platform (FY14) in the northern part of the site;
- at the depth of 3.00 m: contamination with TPH in the pumping station area (FY6);
- at the depth of 4.00 m: contamination with TPH in the area of the former buildings with polluting potential: pumping station (FY6), tanks (FY18) in the northern part of the site;
- at the depth of 5.00 m: contamination with TPH in the tanks (FY18, FY9).
The figures below (nos. 3 ÷ 6) are shown and grouped by areas belonging to the former facilities affected by significant pollution with TPH (mg/kg) in depth.

According to the analysed data, in the area of drillings conducted upstream of the petroleum products storage tanks, the TPH concentrations were below the intervention threshold.

**Figure 3.** Variation of TPH concentrations with depth of the drillings conducted in the tanks area.

**Figure 4.** Variation of TPH concentrations with depth of the drillings conducted in the railway platform area.

**Figure 5.** Variation of TPH concentrations with depth of the drillings conducted between the railway platform and the river.

**Figure 6.** Benzene concentrations in the soil samples taken from drillings.

It can be noted that the areas with significant pollution are within the perimeter of the storage tanks, of the petroleum product unloading platform and in the area between the railway platform and the river.

Following the investigations and the results of laboratory tests, besides the soil pollution with TPH, soil pollution with aromatic hydrocarbons and concentrations of benzene, respectively, was also acknowledged (Figure 6), which exceed the alert threshold in the drillings made in the tanks park area and the railway platform towards the southern part, FY16 and FY18, as well as the intervention threshold in drillings FYP2, FY7, FY18.

Considering the soil permeability and the characteristics of pollutants, the underground water was also investigated by using the monitoring wells and by quarterly measurements in these wells, following which a significant contamination was noticed.
Even the presence of free-phase hydrocarbons was identified, occurring in the form of district pollutant films on the groundwater surface, particularly in the monitoring wells FYP4 (railway platform) and FYP5 (in the tanks park area).

The hydro-observation drillings FYP1 and FYP5, located in the terrace area, have a lower fluctuation of the water table as compared to those in the plain area (FYP2, FYP3 and FYP4), not influenced by the fluctuations of the river water level. Analysing the above graph, it follows that there is a close and interdependent correlation between the levels measured in the hydro-observation drillings FYP2 and FYP3 and the river level; thus, at lower river levels, the hydrostatic level in the two hydro-observation drillings was equally low (the river being a natural receptor) (Figure 7).

Figure 7. Variation of the river water level and of the underground water (hydro-observation drillings)

The general flowing direction of the phreatic aquifer is from NV towards SE, more particularly from the monitoring well FYP1, located upstream of the facilities that have a polluting potential, towards the wells FYP2 and FYP3, located downstream of the specified facilities, near the river course. The phreatic aquifer surrounded by the terrace deposits is supplied from rainfall, whereas the one embedded in the plain is supplied as much from the terrace discharge as from rainfall and from the river.

Figure 8. Quarterly monitoring of TPH concentrations in the underground water.

Figure 9. Quarterly monitoring of benzene concentrations in the underground water.

On the presented graphs (Figure 8 and 9), it can be noted that there is significant pollution with petroleum products and benzene at the underground water level, identified particularly in drillings FYP2, FYP3, FYP4, FYP5.
Conclusions

The pollution of the soil and of the subsoil and, implicitly, of the underground water in the analysed warehouse was favoured by the hydrogeological conditions and by the transport of pollutants, by migration and dispersion of hydrocarbon products.

The contamination of the soil on the site territory covers approximately 67% of its total area.

After analysing the laboratory test results and the isolines with the TPH and BTEX (particularly benzene) concentrations, it follows that there is a contamination of the soil, especially at the former facilities: pumping station, tanks and vehicle platform in the northern part of the site, settling tank, the railway platform spot and the scavenge oil storage area. The contaminated soil layers, following the investigation stage, have identified a contamination of the soil down to the depth of 4.5 – 5.0 m and, considering the presence of the hydrostatic level of the underground water at these depths, an active influential and interdependence connection is noticed between the soil environmental factor and the underground water.

Regarding the aquifer, significant pollution with petroleum products was confirmed at site level, and such contamination with petroleum products tends to also migrate beyond the site. The estimated pollution covers approximately 82% of the total site area.

The most contaminated areas, considering the presence of TPH and BTEX compounds, are the tanks park area and the former railway platform area, which are former facilities needed in conducting the activity, both regarding the soil environmental factor and the underground water.

As short-term measures, it is necessary to build the conceptual model of the site and, based on this, to assess the risks arising from this contaminated site. After that, the best solutions for site remediation (soil and groundwater) will be designed to mitigate these risks.

References:
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