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BOOK OF ABSTRACTS

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CIRCULAR REMEDIATION OF GROUNDWATER CONTAMINATED BY HYDROCARBONS WITHOUT WATER DISCHARGE

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1.Keywords

Groundwater remediation, GreenRemediation, Circular groundwater remediation, UST remediation, Hydrocarbons remediation, MTBE Remediation, Remote control remediation, RiskAnalysis.

1.Introduction

The following application testify that Green Remediation allows, not only environmental sustainable solutions, but also economical advantages and, in this case, it allowed the residential requalification of a dismissed industrial site neglected from 13 years due to the excessive costs of traditional remediation solutions.

Site characterization activities and the Environmental and Sanitary Risk Analysis highlighted unacceptable risks for residential receptors (child and adult) in outdoor and indoor environment and an environmental risk to water resource protection for some organic parameters, mainly aromatic hydrocarbons, total hydrocarbons and MTBE.

The remediation activities, approved by the authorities, for groundwater consist on a site-specific circular remediation that involves hydraulic containment and determines the continuous cycle: "extraction - treatment - injection" of groundwater avoiding water discharges and preserving groundwater.

2. Description or the activities performed

2.1 Characteristics of the site

The case study, a dismissed industrial site, is located in the alluvial plain about 30 km North of Bologna. The subsoil consists of alternating layers of fine sediments, composed mainly by silt, sand and clay distributed in different proportions.

The soil's layers reflect river channel deposits, bank and flood-plains. These sediments belong to the regional hydro stratigraphic unit called A0. The thickness of the sediments can reach up to 20 m with the phreatic zone located in the most superficial layers, with a thickness of approximated 10 m [1] (Figure 1).

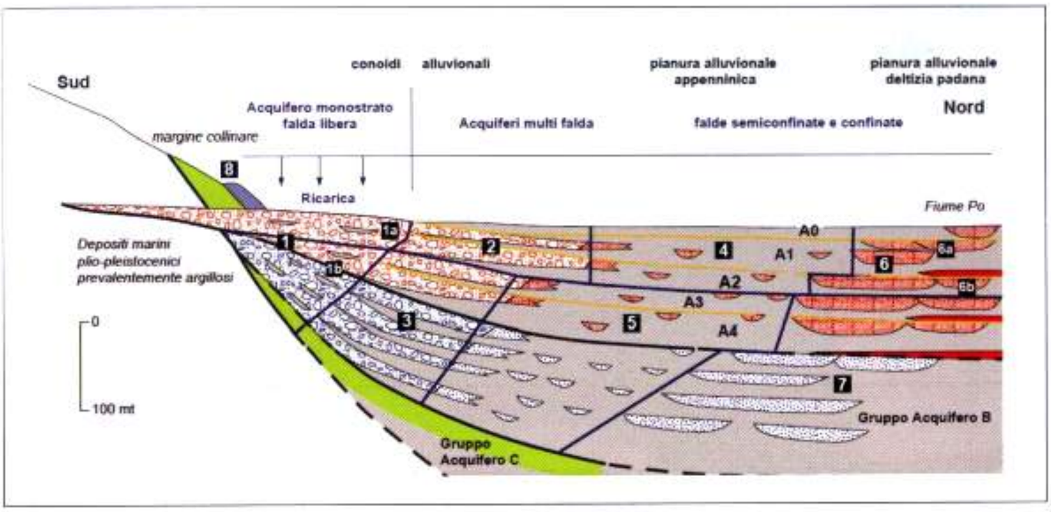

***Figure 1**: Schematic section of the subsoil of the Emilia-Romagna plain from the Apennine to the Po. The aquifer groups are indicated (A, B and C). Alluvial conoids - free aquifers. Multi-layer conoids - upper confined aquifers.*

More than fifteen years ago, during site dismissing, a dozen of underground tanks, with a total capacity of about 200 tons, used for the hydrocarbons storage have been found positioned below the groundwater table level, and removed in compliance with the Italian procedure of the "Messa in Sicurezza di Emergenza" (ex-Decree 471/99).

The subsequent underground remediation required for the secondary source of contamination was interrupted due to excessive clean-up costs. The intended use of the site, from industrial to residential, was tied to the soil and groundwater remediation.

2.2 Site Characterization, Risk analysis and Remediation plan

The site characterization, Risk Analysis and Remediation plan activities included:

- new investigation surveys. The investigations let to detail the activities occurred in the site, restore the piezometer's network monitoring and execute the site characterization;
- the site specific risk analysis in backward mode [2]. The Environmental and Sanitary Risk Analysis highlighted unacceptable risks for residential receptors (child and adult) in outdoor and indoor environment and an environmental risk to water resource protection. The calculation of the *risk threshold concentrations* for the shallow and deep soil have revealed critical issues to some parameters of the hydrocarbon group. The calculations for groundwater, considering *contamination threshold concentrations = risk threshold concentrations* at the *site border point* (conformity point) have revealed critical issues for some organic parameters, mainly aromatic hydrocarbons, total hydrocarbons and MTBE exposed in the following table:

Parameters	Representative concentration of the contamination source (CRS) [mg/l]	Concentration Risk Threshold (CSR) minimum between children and adults [mg/l]	Assessment result
Benzene	3,50E-01	1,00E-03	Non Acceptable
p-Xylene	1,97E-01	1,00E-02	Non Acceptable
Benzo (a) pyrene	5,20E-05	1,00E-05	Non Acceptable
Benzo (g,h,i) perylene	4,50E-05	1,00E-05	Non Acceptable
Benzo (b) fluoranthene	1,00E-04	1,00E-04	Non Acceptable
aliphatic C5-6	1,12E+00	3,50E-01	Non Acceptable
MTBE	2,30E+00	4,00E-02	Non Acceptable

***Table 1**: Risk Analysis assessment results*

- the Remediation Project performed in compliance with the Legislative Decree no. 152/2006 [3]. The project based on the Risk Analysis results, aimed to eliminate the health and environmental risk on the interested environmental matrixes. The final goal of the project is to bring the anomalous concentrations below the risk threshold concentration and ensure acceptable limit concentration at site boundary. The project examined the remediation technologies using the B.A.T.N.E.E.C.[4] criteria taking into account that a residential construction with the building foundations in contact with the subsoil is planned in the area.

2.3 Soil and groundwater Remediation activities

For the three examined environmental matrixes subsoil (<1m), soil (>1m) and groundwater, thanking in account the residential building construction, the following three technical solutions were envisaged:

- subsoil: limited intervention consisting in the removal of the surface soils that caused the health risk;
- soil: proofing measures to insulate the soil to cut off the route of exposure that caused the risk of inhalation;
- groundwater: remediation activities consisting on a site-specific circular clean-up that involves hydraulic containment and determines the continuous cycle: “extraction - treatment - injection” of groundwater avoiding wastewater discharges.

The groundwater remediation system is made by a vertical hydraulic barrier system to prevent the possible migration of dissolved contaminants in groundwater coupled with a groundwater circular remediation. The system has been designed considering the analysis of the groundwater conditions [5] performed by applying the calculation codes of the algorithms provided by the Modflow modeling software [6] (Figure 2).

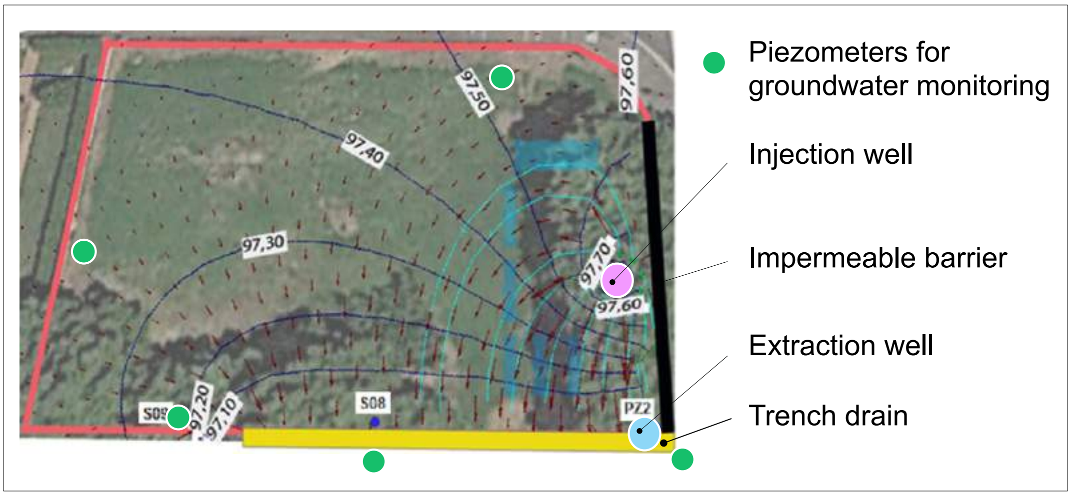

***Figure 2**: view of the site with the location of the system components and model of the underground hydraulic flux at operating conditions.*

The model showed the groundwater trend with the dissolved contaminants resulting from the application of the remediation cycle “extraction - treatment - injection” of groundwater considering the boundary conditions defined by the trench drain, the impermeable barrier, the recovery well and the re-injection well (Figure 3). The water re-circulation in the subsoil remain confined within the site affecting the area occupied by the former underground tanks, with the objective of stimulating the removal of the organic compounds present in the subsoil.

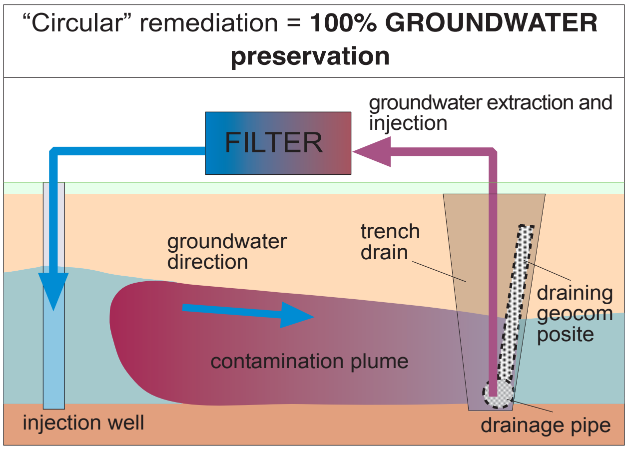

***Figure 3** – scheme of the "extraction - treatment - injection" remediation system*

The principal components of the remediation system are:

- the horizontal passive trench drain with a recovery well to extract groundwater. The drainage trench is positioned down-gradient, with respect to the groundwater flow, at the perimeter area of the site and intercepts the groundwater flow from the contaminated area. The trench consist on a draining geo-composite (geogrid + geotextile) that collect groundwater and a horizontal drainage pipe that conveys groundwater to the extraction well.
- the groundwater treatment system to perform the treatment by means of a sequence of purification. A mechanical filtration to remove iron and manganese naturally present in groundwater in this regional area and an adsorption on activated carbon filters with high capacity to remove organic compounds.
- the injection well to re-entry the treated water in the underground. The injection well is located upstream of the contaminated area and has been dimensioned to allow the absorption in the subsoil of the water extracted downstream and treated by the treatment system.
- the impermeable lateral vertical barrier for the containment of the contaminated groundwater. The barrier is made by a mixture of cement and bentonite to form a diaphragm along the perimeter to the east of the site.
- the remote control system allows to verify and operate, in real-time by web and mobile devices, the main control parameters of the remediation system. The parameters, among others, include: groundwater level in the extraction and injection well, the volume of purified water, the energy supply of the equipment, as summarized in Figure 4.

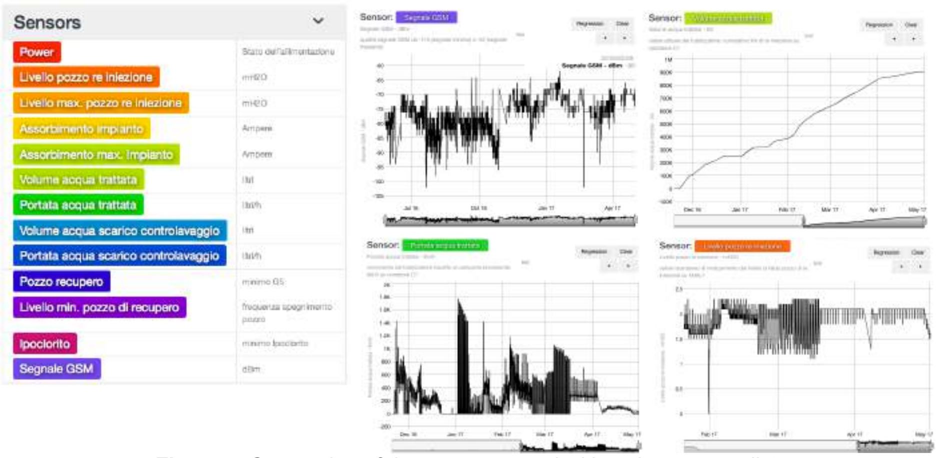

***Figure 4:** Screenshot of the remote control with active sensors list.*

3. Conclusions

The remediation of the site has been planned in agreement with the "Green & Sustainable Remediation" principles and based on an on-site specific hydrogeological assessment. This analysis allowed the planning of the containment of the contamination inside the site area and the removal of the pollutants through the groundwater recirculation: "extraction - treatment - injection".

The remediation costs have been integrated in the economic plan of the area redevelopment investment and do not exceed the 10% of the total costs.

The remediation activities are characterized by the following relevant factors:

- minimum soil movement. 95% of the soil was re-used for the draining trench construction through the application of a specific draining geo-composite (geogrid + geotextile). The geo-composite drain is an innovative solution for the realization of the trenches, it is constituted by a isolated three-dimensional draining structure with a high void index. In the constructive phase it allows the recovery of about 95% of the extracted material excavated for the construction of the trench (Figure 5);

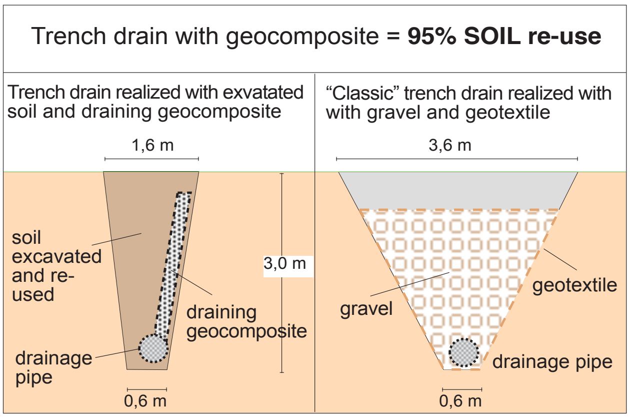

Figure 5 *– scheme of the trench drain to allow soil re-use.*

- total preservation of groundwater. 100% recovery of the remediated water through the re-injection of the decontaminated water flow;
- total re-use of exhausted organic carbon filters. 100% of the exhausted organic carbons are re-used after a dedicated de-absortion process.
- no water discharge. 0% of decontaminated groundwater are discharged in sewer or superficial water after treatment.
- low energy consumption (only one pump is involved into the process) and low environmental impacts.
- minimum travel impacts. 100% of the on-site equipment are controlled in real-time by a remote control system displayed on computer or mobile devices.

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