

**Questionnaire**

**In Situ chemical Reduction**

**IMPEL Project “Water and Land Remediation 2022-24”**

***Delivering time 1 January 2024 – 28 February 2024***

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Context

The contaminated sites management is a process that proceeds at different speeds in Member States. This is due partly to difference in legislation that would mean different definitions - some examples being “potentially contaminated sites”, “contaminated sites”, “remediated sites”.

The contaminated sites management is a process that has different speeds in Members States. This project aims to speed up the process, focusing to the remediation phase that is often the bottleneck, with monitoring parameters specific for each remediation technology, that may show clearly the progress of activities towards the target.

Then, the project has also the objective to promote in situ technologies with a clear scheme for their monitoring over time. These documents will contribute to reduce the use of more impacting remediation technologies like Dig&Dump and Pump&Treat.

The main outcome is to Support/exchange technical experience required in Europe in monitoring in situ/on site technologies order to enable those MS in which no monitoring procedure is currently taking place to have one reference they may use completely or partially.

Introduction

This questionnaire looks at the input of case studies where IN SITU CHEMICAL REDUCTION were applied in a contaminated site.

The questionnaire will remain active in the period comprehended between **1 January 2024 to 29 February 2024** for the collection of case study. Late submission could be evaluated by the project team.

Each case study may have details of the **site location**, details of the **author(s)** and their **affiliation** and **companies** involved. Those information would help in understanding more about the site but are **not mandatory**.

At least one contact point is mandatory, for resolving any potential problem related to the publication.

It is allowed to make reference to registered products and/or patent but it is necessary to make reference to active species present and eventually by-products or side effects (e.g. pH increase).

**Please note:** data on the costs, on environmental net benefit as well as the sustainability aspects are not included in the objective of this study.

The purpose of this Questionnaire is to collect specific information on cases of remediation technology. To do so, you are kindly requested to **submit one or more case studies each with a different file**.

In case you cannot fill the questionnaire please answer to the last question in order address the project team your possible remarks, concerns, requests, suggestions.

As previously mentioned, the responses of the filled Questionnaires will be analysed in order to identify criteria for the evaluation of the performance of the remediation. The experiences collected may be useful to prepare the monitoring plan of different remediation phases for similar cases.

You can both fill the Questionnaire in Annex I and upload documents in English.

Please copy-paste, in the Questionnaire answers, any images, photos, maps, graphs, flowcharts and diagrams that can be useful for a better understanding.

Please send the Questionnaire to [marco.falconi@impel.eu](mailto:marco.falconi@impel.eu).

In case the file of the filled Questionnaire and/or of any useful document attached is too large, please send it/them to via We Transfer (<https://wetransfer.com/>) or Share File (<https://www.sharefile.com/>) or any other preferred internet tool.

**Final note:** The Questionnaire should not be completed only with successful cases of remediation technology application but also with unsuccessful assessment cases; in fact, for those unsuccessful cases, shortcomings and improvement actions will be identified and analysed.

Moreover, feel free to share this questionnaire to inspectors, a public officers or any other stakeholders. Participation or consultancy, site owners, environmental service companies are welcomed.

Thank you very much for your collaboration from all the WLR project team.

If you need assistance or clarifications, you may contact:

Mr. Marco Falconi

Email: marco.falconi@impel.eu

Mobile Phone: +39 3471204170

**DISCLAIMER:**

The questionnaire is subject to the Directive 2003/4/EC of the European Parliament and of the Council of 28 January 2003 on public access to environmental information.

As a consequence, the information contained in the filled Questionnaire will not be confidential, not only for the information of the intended recipient and may be used, published or redistributed by IMPEL without the prior written consent of the compiler.

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**Annex 1**

**In Situ chemical Reduction**

**IMPEL Project “Water and Land Remediation 2022-24”**

***Delivering time 1 January 2024 – 28 February 2024***

1. Your contact details

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| --- | --- |
| * 1. ***Name and Surname\**** |  |
| * 1. ***Country/Jurisdiction*** |  |
| * 1. ***Organisation*** |  |
| * 1. ***Position*** |  |
| * 1. ***Duties*** |  |
| * 1. ***Email address*** |  |
| * 1. ***Phone number*** |  |

\* If you do need, you can fill the Questionnaire as anonymous. In this case, we kindly ask you to fill just the box no. 1.6, 1.7, that will be used to contact you for any problems related to the publication.

1. Site background

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| **2.1****History of the site: Challenges and Solution** |
| Please describe the history of the site (you may add one or more pictures)  Provide some history of the site, why/how it was contaminated, location, current site activities, etc.  What are some of the challenges of this site? -logistics, timing, specific COCs, concentrations, etc.  Why was this technology selected? What problem or challenge does it solve at this site?   * *(your answer) …* * *EXAMPLE OF ANSWER*   *The Tubize Plastics site is located along the banks of the Senne where the river crosses Tubize. From the end of the 19th century to the end of the 20th century, the site was home to the Tubize artificial silk factory, Fabelta-Tubize and Tubize Plastics, which was closed down in 1997. At the end of the 19th century, the Tubize artificial silk factory was started up on the Tubize water mill site along the banks of the Senne River. Later renamed to Fabelta-Tubize, the factory was closed down 1980. In 1983 the site was taken over by Tubize-Plastics which specialized in the manufacture of synthetic fibers, and later polyamide fibers. The company was shut down in 1997. The site was subsequently occupied by various SMEs: recycling of plastics, vehicle scrapping, manufacture of croissants, etc.* |

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| **2.2****Geological and hydrogeological setting** |
| Please describe the geological setting (you may add one or more pictures) of the contaminanted subsurface treated (i.e. permeability, hydraulic gradient, effective porosity, seepage velocity etc.)   * *(your answer) …* * *EXAMPLE OF ANSWER*   The area of investigation consists of a surface layer of concrete which is underlain by gravel and sand fill to a depth of 1,3 m below the ground surface (bgs). Underlying the fill soils are quarternary deposits of gravel and sand colluvium of variable thickness, interbedded with sand and clay layers. Silty clays are encountered below the colluviums between depths of 3,6 to 8,3 m bgs which forms a hydraulic boundary between the overlying quarternary colluvial aquifer and an underlying tertiary (drinking water) aquifer comprising fine to medium sands. The depth to groundwater ranges from 2 to 3 m bgs. |

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| **2.3****Contaminants of concern** |
| Please describe the contaminants of concern and the clean-up goals.  Please include disolved phase concentrations, NAPL, and mass sorbed to saturated soil/fringe (wherever investigated directly or estimated)   * *(your answer) …* * *EXAMPLE OF ANSWER*   A total of 6 subsurface investigations were conducted between 1999 and 2017 in an effort to delineate and quantify the distribution of contaminants underlying the site.  The results of these investigations determined that petroleum hydrocarbon contamination (TPH and BTEX impacts) were largely confined within soils in the unsaturated zone with contaminant concentrations upwards to 5,000 mg/kg and 344 mg/kg respectively. Dissolved- phase contaminant impacts to groundwater within the quaternary aquifer consisted primarily of total chlorinated aliphatic hydrocarbons (CHCs) of upwards to 44,300 μg/L, followed by TPH (2,000 μg/L) and BTEX (1,800 μg/L).  The major component of CHC contamination was cis-1,2 DCE (54%), followed by tetrachlorethylene (“PCE” 28%), and trichloroethylene (“TCE” 16%). The major component of BTEX contamination was trimethylbenzene (TMB >76%) followed by xylenes.  Free-phase oil product was detected at one monitoring well location with an apparent thickness of a few cm.  Calculations to estimate the mass of contaminants present within the quaternary aquifer indicated a total of approximately 3.7 kg of dissolved phase CHCs and 8.7 kg of sorbed phase CHCs respectively. The estimated total of BTEX and TPH contaminants (dissolved and sorbed) was approximately 2.5 kg. Applicable groundwater regulatory limits for contaminants of concern found in groundwater at the site are summarized here: HCs: 20 μg/L, VC: 0.5 μg/L, BTEX: 20 μg/L TMB: 1 μg/L TPHs: 100 μg/L  The delineation of the various contaminants of concern was achieved using a combination of soil probe borings, drilling and sampling of groundwater monitoring wells, and through the use of innovative Direct Push technologies using Geoprobe® drilling equipment and specialized sampling technology such as Membrane Interface Probe (MIP), Screen Point groundwater sampling, and Electrical Conductivity (EC) downhole tools. |

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| **2.4****Regulatory framework** |
| Please describe the regulatory framework applicable.  This should include target values to be reached, , eventual specific approval needed for application of chemicals in the ground   * *(your answer) …* * *EXAMPLE OF ANSWER*   Based upon the results of subsurface contamination quantified at the site, the regional environmental regulatory authority ordered that soil and groundwater remediation efforts be implemented at the site to mitigate contaminant impacts on potential environmental receptors. The specific goal of the regulatory clean up order was to “prevent the danger of contaminant exposure to receptors and prevent the long term spreading of contaminants”. In order to achieve this goal, the regulation requires that “applicable remedial measures be applied to minimize or remove contaminants (i.e decontamination) and to prevent or minimize the spread of contaminants i.e. (containment)”.  A Remediation Action Plan was subsequently requested by the authority to comply with the above mentioned regulatory requirements. The remedial plan submitted to the authority proposed remediation of the heavily impacted unsatured zone soils by excavation and disposal, resulting in the removal of approximately 300 m3 of contaminated soil to a depth of 2 m to 3m bgs. This remedial measure was implemented concurrently with the decommissioning and removal of the existing oil and chemical storage building on the property. There were no specific contaminant clean up criteria for soil quality required for the excavation of impacted surface soils.  For the remediation of dissolved phase contaminants in the unsaturated zone, a feasibility study for the implementation of in situ chemical oxidation (ISCO) and in situ bioremediation (ISBR) was proposed as possible cost-effective and sustainable remediation alternatives to conventional excavation/disposal and large diameter soil replacement borings that were being considered. The results of the study determined that ISCO was a viable approach, although its effectiveness for practical purposes could be severely limited based upon the low hydraulic conductivity of the saturated zone sediments.  Risk-based remediation criteria were developed for CHC contaminants at the site whereby a reduction of total CHC concentrations (i.e for PCE, TCE, DCE and VC) of 95% over 3 consecutive monitoring events in source area monitoring wells was required. |

1. Laboratory-scale application

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| **3.1****Laboratory scale application** |
| Please describe the laboratory scale application (if applicable)   1. Scope of lab test (i.e. is it a comparative test between different chemicals, or one chemical but different dosages, or for evaluation of side effects, etc.) 2. Lab scale test description (batch test/ column test, are blank included, timing, monitoring frequency, monitored parameters, etc) 3. treatment efficiencies of chemical oxidants with specific contaminants 4. the evaluation the oxidant demand due to the soil matrix (i.e. Foc, Soil Oxidant Demand, Base Buffering Capacity etc.) 5. the potential for metals mobilization  * *(your answer) …* * *EXAMPLE OF ANSWER*   *Natural (or matrix) oxidant demand (NOD) and* *Soil Oxidant Demand (SOD) testings ware determined as key parameter that affects the cost and the feasibility of ISCO remediation. NOD is strongly correlated to the mass of oxidant required to overcome the background oxidant demand of the geologic materials (matrix) and/or contaminants.*  *The oxidant demand for each soil sample will be determined by a batch test method using site soil. The oxidant is allowed to react with the soil matrix for a finite time, then the residual oxidant concentration is measured. All samples are kept in an incubator set to 15°C, which is representative of a typical groundwater temperature. Test results are reported in units of g/kg (grams of oxidant consumed per kilogram of soil).*  *The batch test lasted 4 weeks We found that the SOD range were comprehended between 10 and 15 g KMnO4 kg−1 soil.* |

1. Pilot-scale application in field

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| **4.1****Main treatment strategy** |
| Please describe the treatment and the reagent application methods  .  Please describe:   * why the technology was selected; * the application of main reagent and the reasons why it has been selected * What problem or challenge it was solved at this site * Explain the field work, timelines, concentrations, injection strategy, etc. * *(your answer) …* * *EXAMPLE OF ANSWER*   *Ozone is one of the strongest oxidants available for ISCO. It is an allotrope of oxygen and is more soluble than oxygen in water. It is usually generated on site using ozone generators. When typical ozonated feed gases are sparged into tanks containing clean water, the aqueous equilibrium ozone concentrations generally range 5–30 mg/L .* |

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| **4.2****Additives** |
| Please describe the application of additives, stabilizers and/or activators. (e.g. EDTA, iron, high pH etc.) and the reasons why they have been applied  (if applicable)   * *(your answer) …* * *EXAMPLE OF ANSWER*   *The approach used to activate the sulfate radical was the use of elevated pH. In theory, a basic solution should increase the production of hydroxyl free radicals as they can be generated by the reaction of OH⎯ and another radical.* |

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| **4.3 Injection type** |
| Please describe the modality of injection   1. If you used existing wells, or new injection wells, or direct-push injection points, 2. If you used fixed manchette tubs or a combination thereof 3. Your choice for spacing and alignment of injection points (i.e., grid formation, PRB, etc.) or barrier formation, distance between injection points) 4. Information on injection layer (how many meters interval, at which depth from ground level, how it compares with groundwater table and from bottom of the aquifer, does it cover also fringe and yearly fluctuation level) 5. Number of injection campaigns (how many campaigns, distance in time, if for each injection point has been mantained same dosing) 6. ISCO agent dosing 7. Say if you use any injection enhancement (e.g. fracturing)  * *(your answer) …* * *EXAMPLE OF ANSWER*   *7 injection points (1 additional) of sodium permanganate at 15% were performed at depths between 10 and 35 m from pc; The injection pressure was always below 6 bar (as per project); The total volume of reagent injected, using the direct-push system, was approximately 50 m3; The injection of potassium permanganate in a 3% solution was carried out using the MW8, MW10 and MP1-B piezometers, for a total volume of approximately 5.5 m3* |

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| **4.4****Radius of influence** |
| Please describe how do you calculate the radius of inflence by pilot test data   * *(your answer) …* * *EXAMPLE OF ANSWER*   *Radius of influence (ROI) provided for direct push points: 3.5 meters. It was calculated on empirical methods* |

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| **4.5****Control parameters** |
| Please make a list of control parameters for the pilot scale application in field that are helpful for the feasibility full scale.  Field monitoring and sampling program that will adequately monitor both the dispersion of the oxidant and the effectiveness of the treatment in three dimensions. Usually measurements concerning oxidant dispersion are conducted more frequently than COC analysis and are completely different if the oxidants is in liquid or gas form   * *(your answer) …* * *EXAMPLE OF ANSWER*   *The measured parameters were pH, redox potential, temperature, dissolved O2, electrical conductivity, chlorides, Organohalogenated Compounds, Heavy metals (Pb, As, Cu, Zn, Mn, Fe, Cd, Cr VI) and Permanganate (unreacted)*  *Monitoring frequency:*  *• 1st week - all points;*  *• 2nd week - all points 2 times;*  *• Next three weeks - all points 1 time a week;*  *• Three following months - all points 1 time per month* |

1. Full-scale application

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| **5.1****Main Reagent** |
| Please describe the application of main reagent (report and any changes with respect to the pilot scale, or any additional relevant information)   * *(your answer) …* * *EXAMPLE OF ANSWER*   *With respect to the pilot test, it was decided to use 2 different types of reagents: solid potassium permanganate (KMnO4) in a 3% solution and liquid sodium permanganate (NaMnO4) in a 15% solution* |

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| **5.2****Additives** |
| Please describe the application of additives, stabilizers and/or activators.(report and any changes with respect to the pilot scale, or any additional relevant information)   * *(your answer) …* * *EXAMPLE OF ANSWER*   *No changes from pilot to full scale application.* |

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| **5.3 Injection type** |
| Please describe the modality of injection (report and any changes with respect to the pilot scale, or any additional relevant information)   1. existing wells, new injection wells, direct-push injection points, or a combination thereof 2. spacing and alignment of injection points (i.e., grid formation) 3. use of any injection enhancement (e.g. fracturing)“Expected Number of Injection Cycles, as many ISCO surgeries require multiple injection cycles to achieve expected results.  * *(your answer) …* * *EXAMPLE OF ANSWER*   *35 injection points (1 additional) of sodium permanganate at 15% were performed at depths between 10 and 35 m from pc; The injection pressure was always between 6 and 8 bar. The injection of potassium permanganate in a 3% solution was carried out using the 20 piezometers, for a total volume of approximately 30 m3* |

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| **5.4****Radius of influence** |
| Please describe how do you calculate the radius of inflence by field test data (report and any changes with respect to the pilot scale, or any additional relevant information)   * *(your answer) …* * *EXAMPLE OF ANSWER*   *Radius of influence (ROI) provided for direct push points: 3.5 meters in northern area. In eastern area it dropped to 2.5 meters* |

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| **5.5****Process and performance monitoring** |
| Please make a list of control parameters for the full scale application in field that are helpful for understanding the framework of the process and performance monitoring (with parameter, method and frequency)   * *(your answer) …* * *EXAMPLE OF ANSWER*   *The process monitoring lasted 3 years. Here you may find the parameters, methods and frequencies.*   |  |  |  | | --- | --- | --- | | *Parameter* | *Method* | *Frequency* | | *pH* | *Field screening tool* | *Beginning and daily* | | *Temperature* | *Thermocouples* | *Constant* | | *Redox* | *Field screening tool* | *Constant* | | *ORP* | *Application well gauge* | *Daily start and close* | | *DO* | *Downhole field tool* | *Daily start and close* | | *Conductivity* | *Downhole field tool* | *Daily start and close* | | *Iron* | *Field screening tool* | *Daily start and close* | | *VOCs* | *Field screening tool* | *Daily start and close* | | *CO2* | *Downhole field tool* | *Daily start and close* | |

1. Post treatment and/or Long Term Monitoring

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| **6.1** **Post treatment and/or Long Term Monitoring** |
| Please describe the monitoring parameters for post treat ment and long term monitoring (e.g. Monitoring for temperature, presence of residual oxidant, LEL)   * *(your answer) …* * *EXAMPLE OF ANSWER*   *In the period between 2014 and 2020, groundwater monitoring campaigns were carried out on a quarterly basis; The purpose of the monitoring is to verify the effectiveness of the hydraulic barrier of the hydrogeological valley of the former flammable area as well as to verify the '' trend of the concentrations of Organo-Halogen compounds; The discharge limits in the sewerage system have always been respected; The results of the monitoring campaigns have always been sent to the competent authorities, representing, in fact, the starting point for the '' Site-Specific Risk Analysis and for the development of the Full Scale Remediation Project; All project proposals were discussed in concert with the relevant Bodies, through Technical meetings.* |

1. Additional information

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| **7.1****Lesson learnt** |
| Please describe Key findings and lessons learned about this site  (difficulties and weaknesses, successes and strengths, keystones, shortcomings and rooms for improvement. Please give your opinions as regard to 1) methodology and procedures, 2) technical aspects 3) legislative, organizational aspects and add site specific information ( other contaminants present (below thresold values), background levels of metals and/or contaminants or components, organic matter, BOD, COD, eventual remediation activities already performed on site in the past, accessibility of the area (maybe there are some buildings on top of source area, or some subservices that need to be preserved during treatment), etc.)   * *(your answer) …*   . |

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| **7.2****Additional information** |
| Given the clues and the evidence found in the specific case, can you suggest criteria for the determination of clues and evidence referable to the success of remediation?   * *(your answer) …* |

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| **7.3****Training need** |
| Please give your opinion as regard to the training needs from the technical, procedural, organizational point of view and which training tool you think is effective (workshops, training on-the job, webinars, e-learning, etc.).   * *(your answer) …* |

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| **7.4** **Additional remarks** |
| Please feel free to give any additional information, remarks, concerns, requests, suggestions   * *(your answer) …* |

Glossary of Terms

A glossary will help a you to maintain the level of precision necessary for key terms and maintain consistency across the text. We found out that sometimes terms that sounds similar like “contaminated” and “polluted” are used in the same way as synonyms in some country, while in other they have different meanings (due to legislation or for other reasons). So fill in this glossary for your key elements and of course for acronyms.

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| **Term (alphabetical order)** | **Definition** |
| VOC | Volatile organic compounds (VOCs) are organic chemicals that have a high vapor pressure at ordinary room temperature |
| .... | ..... |
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