

**Questionnaire**

**Solidification/Stabilization**

**IMPEL Project “Water and Land Remediation 2025-27”**

***Delivery time 1 May 2025 – 30 September 2025***

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Context

Contaminated sites management is a process that proceeds at different speeds in the EU Member States. This is partly due partly to differences in legislation which implies different definitions. Some examples of terms with different definitions are “potentially contaminated sites”, “contaminated sites”, “remediated sites”.

This project aims to speed up contaminated sites management, focusing to the remediation phase that is often the bottleneck. It includes a focus on monitoring parameters specific for each remediation technology, that may clearly show the progress of activities leading towards the remediation target.

Moreover, the project has also the objective to promote sustainable in situ technologies with a clear scheme for their monitoring over time. The resulting documents will contribute to reduce the use of less sustainable remediation technologies like Dig&Dump and Pump&Treat.

The main outcome is the support/exchange of technical experiences, required in Europe in monitoring in situ/on site technologies. This enables those MS in which no monitoring procedure is currently available, to have one reference they may use completely or partially.

Introduction

This questionnaire focuses on case studies where Solidification/Stabilization (S/S) were applied at a contaminated site.

The questionnaire for the collection of case studies will remain active in the period between **1 May 2025 to 30 September 2025**. Late submission could be evaluated by the project team.

The purpose of this Questionnaire is to collect specific information on cases of Solidification/Stabilization (S/S). To this purpose, you are kindly requested to **submit one or more case studies each with a different file**.

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

For each case study may details on the **site location**, details of the **author(s)** and their **affiliation** and **companies** involved are inventoried. This information would help understanding the site, but is **not mandatory**. At least one contact point is mandatory, for possible questions or resolving any potential problem related to the publication.

It is allowed to make reference to registered products and/or patents, 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 Questionnaire and the resulting report.

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

You are requested to fill out 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**

**Solidification/Stabilization**

**IMPEL Project “Water and Land Remediation 2025-27”**

***Delivering time 1 May 2025 – 5 September 2025***

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   Hercules Incorporated began producing toxaphene in 1948 and continued production through 1980. Toxaphene was one of the most heavily used insecticides in the United States until 1982, when the United States Environmental Protection Agency (EPA) cancelled the registrations of toxaphene for most uses. A registration is a license allowing a pesticide product to be sold and distributed for specific uses in accordance with specific use instructions, precautions, and other terms and conditions. All uses of toxaphene were banned by the EPA in 1990.  Between 1975 and 1980, Hercules Incorporated operated the 009 Landfill under a permit issued by the Georgia Environmental Protection Division (GEPD). The permit allowed the Brunswick, Georgia, Hercules plant to dispose of waste water sludge from the production of toxaphene. Part of the Hercules 009 Landfill was also used for disposing empty toxaphene drums and toxaphene-contaminated glassware, rubble, and trash. The landfill was constructed as 6 cells divided by subsurface berms reportedly lined with a soil-bentonite clay mixture across the bottom and along the bermed walls. The landfill was closed in 1983. The EPA added the Hercules 009 Landfill to the Superfund National Priority List in 1984. Hercules designed and implemented the remedy for the site. |

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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*  The so-called ‘red’ waste consisted of about 60,000 tons of roasted pyrite ashes. Consequently the material was very acidic. Its texture was silty but was not cohesive. The ‘grey’ waste consisted of 75,000 tons of very cohesive alkaline gypsum precipitate from water treatment operations employing excess lime. Composition is outlined in the table below.      Result of the leaching test |

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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  Due to the large volume of material to be treated, the option to keep the material on-site was preferred. Therefore, the wastes had to be treated to reduce leaching (and in order to fulfil the European Waste Acceptance Criteria for hazardous waste landfills) stored above groundwater and underneath an HDPE liner, to prevent rain percolation. |

1. Laboratory-scale application or field tests

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| **3.1****Laboratory scale application or field tests** |
| Please describe the laboratory scale application or field tests (if applicable)   1. Scope of lab test (i.e. is it a comparative test between different binding materials, 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. immobilization efficiency with specific contaminants 4. the potential for mobilization   (your answer) …  -------------------------------------------------------------------------------------------------------------------  EXAMPLE OF ANSWER  During the remedial design process, various laboratory-scale tests were carried out to determine the appropriate additive for immobilising the TBT. Some experience was already gained from testing of TBT contaminated sediments from the port of Zeebrugge, Belgium (Table 1).  The latter showed that stabilization with cement is not working at all, as expected from literature as TBT becomes very soluble at high pH. A commercial product, E-clays (Envirotreat, UK), although being on previous TBT stabilization projects, did not show any positive result.  The proprietary product Organodec, which is based on biochar, gave promising results, but when combined with cement the positive effect was diluted (Table 2). It was therefore decided to only use the addition of 2 % of Organodec in the Guernsey project.  The sediment was treated by means of a rotary mixing bucket (brand Allu) mounted on an excavator.  The production rate was about 30 tons an hour, and dosing was done by spreading 500 kg of Organodec (after soaking to prevent dust) over a batch of 16 m³ (about 25 tons) of sediments. Mixing was carried out 3 times to ensure a sufficiently uniform distribution of additive.    Table: Lab scale stabilization tests on Zeebrugge sediment, 1 OrganoDEC = patented additive; 2 OPC = Ordinary Portland Cement; 3 E-clay = environmental clay    Table: Lab scale stabilization tests on Guernsey sediment. 1 OrganoDEC = patented additive; 2 OPC = Ordinary Portland Cement |

1. Full-scale application

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| **4.1****Main treatment strategy** |
| Please describe the treatment and the binder application methods  .  Please describe:   * why the technology was selected; * the application of main binder and the reasons why it has been selected * What problem or challenge it was solved at this site * Explain the field work, timelines, concentrations, mixing strategy, etc.   (your answer) …  -------------------------------------------------------------------------------------------------------------------  EXAMPLE OF ANSWER  Geo-Con was contracted by the DuPont de Nemours and Company, to stabilize contaminated soils at the DuPont Martinsville Unit I ISM Remediation site using In-situ Stabilization. Treatment involved the application of zero valent iron and Kaolin clay.  Zero valent iron was selected based on the primary contaminant of concern, carbon tetrachloride. Kaolin clay was used to minimize groundwater flow through the treatment zone. Elevated levels of carbon tetrachloride were identified on-site in the existing soil and groundwater with shallow soil concentrations as high as 30,000 mg/kg. Other contaminants detected included chloroform, methylene chloride, dichloroethylene, barium and chromium.  Geo-Con’s scope consisted of in-situ treatment of 5,000 yd3 of soil by the Shallow Soil Mixing technology (SSM), without excavation of removal.  In this application, Geo-Con used a Cassagrande Model CM15 crane-mounted drill rig to support the soil mixing operation. A wet or hollow Kelly bar connects the mix auger with the drill turntable and carries slurry from the plant to the auger.  An 8-ft diameter mixing-auger was used to produce a homogeneous soil mix column. The zero valent iron/kaolin clay slurry was applied as specified to a depth of 35 ft. The 8-ft diameter columns were spaced to provide complete coverage of the treatment areas.  Kaolin clay slurry was prepared in Geo-Con’s on-site mixing plant and was injected as the mixing auger was advanced downward to the maximum treatment depth of 35 ft to create the appropriate soil mix proportions within the column. The SSM columns were laid out to provide full coverage for the 3 rates of reagent dosage required at the site.  Once the Kaolin clay was injected and the column thoroughly mixed, iron was added by driving in a steel casing, filled with the prescribed amount of iron for the column, then pulling out leaving the sacrificial drive point and the iron in place. By proper sizing of the casing for the specific iron application rate, the iron was distributed evenly over the length of the column. The column was then remixed from top to bottom. Cement was incorporated into the upper 20 ft of treated soil to improve the workability of the treated soil so that it could be graded and capped.  A total of 78 columns were successfully installed to treat the designated area. A sampling program was implemented to verify the amount of iron installed. Selected columns were sampled at 10-ft intervals with Geo-Con’s SSM sampling tool. |

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| **4.2****Additives** |
| Please describe the application of additives, (e.g. EDTA, iron, high pH etc.) and the reasons why they have been applied  (if applicable)  (your answer) …  -------------------------------------------------------------------------------------------------------------------  EXAMPLE OF ANSWER    The acidic ‘red’ waste had sufficient geotechnical properties, and only a reduction of arsenic leaching was required. This was achieved by adding 1 w/w% of zero valent iron. An alternative approach, based on cement-based solidification also decreased arsenic leaching, but strongly increased the release of cyanide to unacceptable levels.  The alkaline ‘grey’ waste had to be geotechnically improved, so a cementitious binder was required, but the use of cement and lime was not possible, and a strong impermeable matrix was achieved by adding 40 w/w% of a binder consisting of Portland cement and GGBS (ground granulated blast furnace slag). An interesting chemical stabilization of cyanide in the form of ‘Prussian Blue’, was also investigated but did not work sufficiently.  The whole project had to be carried out in a very short time-frame of only 8 months. Therefore, both wastes were mixed in parallel in two different plants, each with a throughput of around 150 tons an hour.  The non-cohesive ‘red’ waste was mixed with the iron powder by means of a continuous liming mixer (pictured left). The cohesive ‘grey’ waste was mixed in a batch concrete mixing plant. |

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| **4.3 Equipment** |
| Please describe the equipment used  (your answer) …  -------------------------------------------------------------------------------------------------------------------  EXAMPLE OF ANSWER  An excavator was used to mix the landfill contents with the Portland cement. The landfill was divided into 25 x 25-ft (7.6 x 7.6-m) square cells for treatment. The total wet weight of the untreated soil and sludge in the cell was determined using a density of 100 lb/ft3 (1600 kg/m3) and the depth of untreated soil or sludge in the cell. Based on the total wet weight of the soil and sludge in the cell, the amount of Portland cement required for treatment was calculated. Up to 6 subcells were treated at one time. The remedial action contractor used an excavator to mix dry cement into the contaminated material while the material remained in place. Water for hydration of the cement was added as needed. Records were kept including depths of treatment of the “as-treated” (as-built) subcells. The depth of treatment extended below the bottom of the landfill contents sludge zone adding to the total volume of material to be treated. The treated depth of the majority of subcells extended into the regional groundwater table.  The remedial action construction was completed by regrading and revegetating the site. The primary intent of this activity was to establish an adequate vegetative cover over the soil-cement cap, the stabilized landfill contents, and other disturbed areas of the site resulting from remedial action activities. Rough grading involved adding some selected fill from a nearby borrow area. During this fill placement, these areas were rough graded and compacted to promote positive drainage. A vegetative cap was placed on top of the graded area comprised of 6-in of loose fill, which was fertilized and seeded. |

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| **4.4****Challenges encountered** |
| Please describe any challenges encountered during the full scale application  (your answer) …  -------------------------------------------------------------------------------------------------------------------  EXAMPLE OF ANSWER  A significant challenge on the project was the presence of buried obstructions encountered during the mixing of the wall, including boulders, timbers, and steel cables. The obstructions required selective removed from the alignment with an excavator, so that all columns could be installed.  Ambient air in work zone air-monitoring was carried out on this site every one to two hours of production, because of the potential for encountering buried trash at the site. |

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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.  (your answer) …  -------------------------------------------------------------------------------------------------------------------  EXAMPLE OF ANSWER  Soil mix samples were tested for iron content using a wet wash and iron separation test. Results of sampling indicated the average iron content of each column was greater than required and no individual samples were more than 20% less than the required iron concentration.  Control of both carbon tetrachloride emissions and migrant nuisance odours to prevent activation of off-site alarms both real and perceived were a significant concern. Controls implemented included staged mixing and excavation, plastic liners, tarps and application of latex foam. Other work related to the Unit I ISM Remediation included demolition and removal of buried utilities and concrete structures, abandonment of monitoring wells and construction of an asphalt cap. |

1. Post treatment and/or Long Term Monitoring

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| **5.1** **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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| **6.1****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  (your answer) …  ------------------------------------------------------------------------------------------------------------------- |

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| **6.2****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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| **6.3****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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| **6.4** **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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