



Treatability of polluted soils

Methodology guidelines for the technique selection
and performance assessment



SUMMARY

ADEME



Agence de l'Environnement
et de la Maîtrise de l'Énergie



Context

The use of appropriate means to treat sources of site pollution and to control environmental pollution is covered by the Management Plan defined by the ministerial note of February 8th 2007 pertaining to polluted site management and redevelopment methods.

This management plan recommends, when justified by the situation, the implementation of pollution control techniques in view of managing the sources of pollution and their impact on the population and the environment.

Various solutions are considered, depending on the redevelopment projects, the site's intended use and the risk reduction goals defined. The treatment method must be selected during this step. The decision maker must then deal with various types of situation governed by :

- Technology-related uncertainties (process under development, relevance to the case to be treated, etc.)
- Performance-related uncertainties (limited references for the type of pollution to treat, restrictive treatment goals, heterogeneous and difficult to accurately characterise pollution, process management, etc.)

In the worst case, where experience feedback concerning available technologies and their performance

do not allow the selection of a suitable treatment technique to achieve the risk reduction goals, the decision maker must have access to a standard procedure enabling it to define the most suitable treatment technique in light of the defined goals.

In this perspective ADEME has been running, since 1999, a study programme aimed at defining such a methodology enabling, on the one hand, the selection of applicable techniques and, on the other hand, the prior performance assessment of the selected techniques.

Issues tested while drafting

The decision support tool was developed by applying the treatment tests and characterisations, proposed by the programme partner teams, to 8 distinct soils collected from the following types of polluted sites :

1. Former gasworks or coking plant
2. Oil storage site
3. Surface treatment activity
4. Non-ferrous metal metallurgy activity
5. Manufacture or use of wood treatment products
6. Former mining sites
7. Solvent regeneration activity
8. Accidental PCB pollution

These eight cases were selected by the ADEME based on the main types

of activity and typical pollutants identified amongst the main sources of soil pollution by the 1996 survey conducted by the Office of the Secretary of State for the environment.

Amongst the 400 clearly identified cases, the selection took into account :

- All major pollutants encountered, either alone or in mixtures;
- The main typical pollution-generating activities or circumstances;
- As many configurations encountered at sites as possible (soil pollution alone or soil and water table, waste or soil source term, etc.);
- The need to be able to test all treatment techniques selected by the ADEME. This choice is based on expert opinions and on application cases shown to be adapted .

All of these issues pertain to a pollution source located in the unsaturated zone. Test and characterisation procedures have thus been defined for this type of situation. Nevertheless, the scope of these guidelines is not limited to these situations alone and the case of sources of pollution located in the saturated zone has been taken into account in the final version of the guidelines.

List of techniques taken into account

The 11 technical families or groups selected in these guidelines are as follows :

- Biodegradation
- Bio-immobilisation
- Bioleaching
- In situ chemical oxidation
- Physical or physicochemical sorting operations
- Physicochemical stabilisation
- Phytoextraction
- Phytostabilisation
- Reduced pressure extraction and multi-phase extraction
- Thermal desorption
- Washing with chemical agents and surfactants

These techniques can be arranged in sub-groups. Thus, we can distinguish :

- techniques aimed at breaking the pollutants down.
- techniques aimed at separating pollutants from the solid matrix,
- techniques aimed at stabilising the pollutants

A detailed presentation of these techniques is provided in the reference document appended to the methodology guidelines.

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- POLDEN - State of the art of soil pollution control techniques / Internal document;
 - USEPA - "Guide for conducting treatability studies under CERCLA";
 - Water agency guidelines - "Water table decontamination : state of the art";
 - ADEME - Biological treatment techniques for polluted soils - 1998;
 - POLDEN document for the ADEME - Treatment techniques by stabilisation of polluted soils - 1995;
 - CNRSP / EPF guidelines - Nord-Pas de Calais
 - POLDEN's experience



This decision-support tool comprises a guidelines document and appendices

Methodology guidelines

The methodology guidelines are intended for the main stakeholders involved in the remediation of the polluted site and first and foremost for the decision maker responsible for the polluted site remediation operations: individuals or corporate bodies, site operators or developers, whether industrial, private, representatives of local authorities, or public or private developers. The decision maker's advisors (consultant engineers, technical design offices, etc.) and project managers (technical pollution control and remediation service providers) may also make use of these guidelines in view of submitting preselected technical solutions to the entity in charge of remediation.

Indeed, these guidelines are intended for the preselection of techniques by the decision maker, in view of discarding any clearly inappropriate techniques based on the knowledge of simple site, pollutant and soil-related parameters and to identify those parameters likely to limit the feasibility and performance of the techniques. These guidelines lead to the preselection of techniques that must then be subjected to additional treatment and characterisation tests in view of ascertaining their feasibility and ability to achieve the goals. A consultation of specialist companies may then be initiated in view of conducting these treatment tests in accordance with the specifications presented in the appendix.

If not technically competent in the field of polluted sites, the decision maker may be advised by a service provider with the required expertise.

The preselection method must involve the following steps :

1. Preamble : minimum required knowledge

The decision maker must first ensure it possesses sufficient knowledge concerning the types of pollutant to treat, the boundaries of the polluted area to treat, the concentration levels encountered at various points within this area and its location relative to the saturated zone, the access conditions to this area of polluted soil to treat and finally, the desired treatment outcome goals.

2. Preselection of techniques

The procedure follows a logical tree path, starting from the general site properties, pollutant(s) to treat and soil matrix and leading to more specific properties requiring the analysis and testing of samples representative of the soil to treat. During this procedure, a number of parameters appear, some of which serve to exclude the feasibility of a given technique (exclusion parameters), while others (limiting parameters) render the applicability of a technique more complex or fastidious.

3. Summary of preselection results

The preselected techniques are compared with respect to the limiting parameters specific to each technique

and to additional criteria concerning the technique's development status, frequency of use, order of magnitude and treatment duration and costs.

On completion of the preselection process, the decision maker may consult with service providers specialized in conducting treatment tests in view of ascertaining treatment feasibility according to the preselected techniques. For this, the characterisation and treatment tests must conform to the specifications defined for each of the techniques.

Should a service provider propose the use of a new technique not listed in the guidelines, it must refer to the specifications provided for this purpose and serving to compare the application conditions of this technique to the preselected conditions.

The 3 appended documents serve as a support for the decision maker to ensure treatment feasibility by the preselected techniques.

Associated specifications

The associated specifications are intended to enable treatment test service providers (design offices, test laboratories, pollution control operators) to conduct additional tests and characterisation operations in accordance with standardized protocols, in view of ascertaining treatment feasibility and the achievement of treatment goals using the techniques preselected by the decision maker.

The specifications for each technique are built according to the following steps :

1. Orientation tests
2. Characterisation in view of performance assessment
3. Performance assessment
4. Summary of results

Finally, the results of the assessment of each tested technique are compared according to the frame used for the summary of results.

The treatability of a polluted soil by a given technique must be validated, according to the defined goals, by comparing the initial and final characterisation results of either pollutant content, or pollutant availability.

Orientation tests

Generally conducted using laboratory systems, the orientation tests described in the guidelines enable, depending on the technique, either to directly test treatment feasibility on the considered soil sample, under controlled conditions, defining the optimum operating conditions for subsequent tests, or to direct the treatment feasibility study towards a type of assessed technique implementation procedure, prior to defining, under controlled conditions, the feasibility of the considered soil sample treatment using the most appropriate procedure. This step in the method is conducted using a decision chart.

The principle of orientation tests generally consists in monitoring the drop in pollutant concentration or availability according to the imposed



conditions corresponding to the application of a recognized physical, physicochemical or biological principle. The results of the orientation tests are used to define, within the considered situation, whether :

- the preselected technique is applicable in view of the defined treatment goals and whether it is worthy of pilot-level assessment,
- after pre-treatment, the technique would allow the defined goals to be achieved,
- this technique may be considered as a pre-treatment step in another treatment technique.

Characterisation in view of performance assessment

In preparation for and prior to the assessment of the techniques' expected performance, they should be characterised in light of the goals defined for the destination of the treated soil.

Thus, to determine the technique's aptitude to achieve the predefined treatment goals, the treated soil's total pollutant content is determined, after mineralization for mineral compounds or after extraction for organic compounds, according to the type of pollution taken into consideration in the site's conceptual schema. A "scan" (extended analysis) of soil mineral and organic composition serves to ensure that the treatment has not led to new soil contamination. The analyses must also pertain to those parameters and/or substances likely to be contributed by the treatment process implemented.

The influence of treatment on the leachable fraction of the soil can be estimated by using the NF ISO/TS 21268-2 leaching test. The parameters detected in the leaching eluate are the characteristic parameters identified during the previous diagnostic phases.

The influence of treatment on soil leaching behaviour can also be assessed in a manner more representative of the soil's exposure conditions using an NF ISO/TS 21268-3 column percolation test. Other test systems using the same type of approach can also be used to ascertain the salting-out of pollutants from the soil in a different scenario (no percolation, water table up-flow, etc.).

These systems are standardized by ISO (TC 190/SC7/WG6) and AFNOR (X 31-E – Leaching topic) workgroups. The parameters detected in the behaviour test eluates are the characteristic parameters identified during the previous diagnostic phases, the characteristic breakdown intermediates shall also be detected in the case of organic pollution.

When the soil is to be excavated for treatment, two types of treated soil destinations may be considered :

- Disposal to waste storage facilities ;
 - Reuse at the same or a different site.
- Soil characterisation must thus take into account, depending on the case, the storage facility admission conditions, or the acceptable conditions for soil reuse.

If the intended destination for the treated soil is an inert waste storage facility, the parameters are those of the French Order of March 15th 2006 defining the criteria for waste admission to inert waste storage facilities.

Furthermore, depending upon the conditions of site use, the list of possible characteristics may be completed by some measurements or tests intended to characterise soil fertility in view of implementing plant cover.

Finally, in view of achieving a global method for assessing the decrease in soil environmental impact, the ADEME proposed the possibility, during the performance assessment approach, of conducting comparative ecotoxicity tests before and after treatment.

The influence of treatment and of a soil percolation solution on soil ecotoxicity is determined by comparison of the effects of treated and untreated soil, along with their respective percolates, on test organisms. It has thus been observed in certain situations, that treatment leading to reduced pollutant content in soil actually causes increased ecotoxicity of the treated soil, either by contribution of ecotoxic substances, or by inducing a lack of certain nutrients.

Performance assessment

Generally conducted using pilot systems, the expected performance assessment tests described in the guidelines serve to validate the

results of the orientation tests at an intermediate scale, closer to industrial conditions, and to highlight any operating difficulties in achieving the expected results, on a large scale, based on the orientation tests. These tests also serve to prepare a sample representative of treatment capacity using the studied technique, in view of performing a comparative assessment of pollutant content and availability (depending on the destination of the treated soil) and of the fertility of treated and untreated soil.

In the same manner as for the orientation tests, the principle of expected performance assessment tests is generally based on monitoring the reduction of pollutant content or availability under imposed conditions (at a larger scale) corresponding to the application of an acknowledged physical, physicochemical or biological principle.

The results of the expected performance assessment tests are used to define, within the considered situation, whether the technique arising from the orientation tests is applicable in view of the defined treatment goals, or whether, after pre-treatment, the technique would allow the defined goals to be achieved, or moreover whether this technique may be considered as a pre-treatment step in another treatment technique.

Summary of results

The results of soil treatability assessment by a considered technique provide the user with a global vision of a treatment's technical feasibility; of its aptitude to achieve the defined goals in terms of pollutant content or availability reduction, but also of its effect in terms of ecotoxicity of the soil or of a solution obtained by soil percolation, or of its aptitude for revegetation, and finally of the means involved.

Finally for applicable techniques, cost, safety and uncertainty elements, to be defined on completion of the tests, are used to complete the user's information concerning the treatment techniques adapted to the issue at hand.

Other appended documents

The reference document gives a description of the different techniques covered in the guidelines, along with any related experience feedback.

The bibliographical references enable users of the guidelines to further their knowledge of the various techniques covered.



The creation of this methodology tool is the result of a three-stage programme

Stage 1 (1999 - 2003 period)

Collaboration of eight teams specialized in each of the techniques selected by the ADEME in view of developing a study methodology for the feasibility of each technique covered by the guidelines. These eight teams, along with the techniques respectively tested, are as follows :

- PROCEDIS, for pilot-scale thermal desorption tests;
- LACE / Claude Bernard Lyon 1 University (since renamed IRCE-LYON), for the thermal desorption orientation and reduced pressure extraction tests;
- LAEPSI / Lyon INSA (since renamed LGCIE), for the bio-immobilisation and bioleaching orientation tests (excluding sulphate-reducing bacteria);
- Materials Physicochemistry Laboratory / BRGM (since renamed the Environmental Processes Department), for physical or physicochemical sorting and chemical washing tests;
- The Department of Biotechnology and Hydrometallurgy Processes / BRGM (since renamed the Environmental Processes Department), for bioleaching orientation tests on sulphate-reducing bacteria and pilot tests;
- The French Petroleum Institute's Microbiology Department, for hydrocarbon and chlorinated solvent biodegradation tests
- The Soils and Environment Laboratory / ENSAIA - INRA, for the phytoextraction and phytostabilisation tests;
- The Process Study and Analysis Department / COGEMA (since renamed AREVA), for the physico-chemical stabilisation tests

The coordination of this teamwork was entrusted to INSAVALOR-Division POLDEN. This work led the ADEME, in 2003, to publish a "Test version" of the "Soil treatment tests" guidelines intended for application in several distinct cases.

→ June 19th 2003 : "Treatment of polluted soils - how to secure the choice of techniques ?" presentation and exchange meeting (ADEME - Maison de la chimie, Paris)

Stage 2 (2003 - 2007 period)

Application of the methodology in three distinct site pollution cases, in view of validating the method's applicability and defining any improvements required. The three cases of site pollution giving rise to method application pertained to the following situations :

- Treatment of mixed chlorinated solvent / total hydrocarbon pollution ;
- In situ treatment of a former gasworks ;
- In situ treatment of a site polluted with aliphatic organochlorinated compounds.

These applications, conducted by the Biobasic Environnement and BURGEAP design offices, with the participation of the IFP and AKZO NOBEL, for the account of industrial companies, led to a revision of the guidelines intended, in particular, to render them more operational.

→ November 28th 2006 : Polluted soil treatment conference - experience feedback on the "Treatability" technique selection and performance assessment method (ADEME - POLLUTEC Trade Fair, Lyon)

Stage 3 (2008)

Updating of the guidelines based on the conclusions of the three application programmes. This update consists in :

- Extending method application to the treatment of sources of pollution present in the saturated zone, not covered by the initial version of the guidelines;
- Integrating the remarks and conclusions of the three method validation programmes;
- Integrating the in situ chemical oxidation technique;
- Creating a specifications template containing the essential information to be collected in the event of addition of other soil treatment techniques;
- Restructuring the guidelines in an upgradable form to render them more easily operational. This new structure consists, on the one hand, in an abbreviated version of the guidelines and, on the other hand, in a set of support documents providing the decision maker with all documentary elements, along with the characterisation and test specifications required to select the most suitable techniques for the treatment of the site concerned.

This update was performed by INSAVALOR Division POLDEN, with the participation of BRGM's Environmental Processes Department and of the INSA Lyon Civil and Environmental Engineering Laboratory.

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**You can download FREE OF CHARGE:
The methodology guidelines,
The associated specifications for the tests of treatment,
The reference document
www.ademe.fr/SPS**

About ADEME

The French Environment and Energy Management Agency (ADEME) is a public agency under the joint authority of the Ministry for Ecology, Energy, Sustainable Development and the Sea, and the Ministry of higher Education and Research. The agency is active in the implementation of public policy in the areas of the environment, energy and sustainable development.

ADEME provides expertise and advisory services to businesses, local authorities and communities, government bodies and the public at large, to enable them to establish and consolidate their environmental action. As part of this work the agency helps finance projects, from research to implementation, in the areas of waste management, soil conservation, energy efficiency and renewable energy, air quality and noise abatement.



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