SUMMARY REPORT

Implementation of Sustainability in Management of Contaminated Land

—

in particular using emerging 'green' technologies

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- The members of the Organising Committee:
  - Arthurt de Groof – Gronitmij, The Netherlands (Chair)
  - Hans-Peter Koschitzky – University of Stuttgart, Germany (Vice-chair)
  - Paul Bardos – R3 Environmental, United Kingdom
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  - Philippe Menoud – DuPont, Switzerland
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  - Elise Noel – Shell, France
  - Matthew Pearce – WorleyParsons, United Kingdom
  - Alan Thomas – ERM, United Kingdom
  - Peter Wouters – ENVIRON, Spain

NICOLE is a network for the stimulation, dissemination and exchange of knowledge about all aspects of industrially contaminated land. Its 100 members of 20 European countries come from industrial companies and trade organizations (problem holders), service providers/ technology developers, universities and independent research organizations (problem solvers) and governmental organizations (policy makers).

The network started in February 1996 as a concerted action under the 4th Framework Programme of the European Community. Since February 1999 NICOLE has been self-supporting and is financed by the fees of its members.

More about NICOLE on www.nicole.org
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Program NICOLE Technical Meeting
1. Introduction

1.1 General

NICOLE has described a sustainable remediation project as one that represents the best solution when considering environmental, social as well as economic factors – as agreed by the stakeholders. This debate has been the subject of several NICOLE meetings and special sessions, for example:

- Management of Contaminated Land towards a Sustainable Future: Opportunities, Challenges and Barriers for the Sustainable Management of Contaminated Land in Europe, Barcelona, Spain, 12 – 14 March 2003
- Sustainable Remediation, London, UK, 3 March 2008 (with SAGTA)
- Sustainable remediation – A solution to an unsustainable past? Leuven, Belgium, 4-5 June 2009.

These workshops were significant contributions to the development of an international discussion of sustainable remediation. They also supported the development of NICOLE’s *Road Map for Sustainable Remediation* published in 2011, its subsequent supporting guidance and the 2013 joint statement with the COMMON FORUM on Risk-Informed and Sustainable Remediation. All of these resources and the workshop reports are available as downloads free of charge from www.nicole.org. Some additional background is given in Chapter 2.

The workshop in Lisbon represents a decisive shift towards reporting practical implementation of sustainable remediation projects and policies. Related to, and part of, the sustainable remediation topic are the concepts of Green Remediation which has been developed largely by the US EPA, and a discussion of green technologies meaning technologies which are considered to have, as intrinsic property, a relatively low environmental impact, for example being less intensive in their use of resources and more protective of soil functionality. Sustainable remediation, green remediation and green technologies are inter-related but they are not interchangeable terms.

The Lisbon Workshop 2013 gathered examples and experiences on how contaminated sites can be remediated eco-efficiently, leaving a smaller environmental footprint, and how their reuse can contribute to a more sustainable development. This encompassed both approaches to deployment and decision-making, and technologies.

The overarching aims of the workshop were to facilitate adoption of more sustainable strategies and techniques, and to understand whether there are barriers to this, and if so, how they could be overcome.

The workshop began with a keynote paper to provide a common vocabulary for the themes and ideas being presented, and was then organised in several sessions: Development of sustainability frameworks; Implementing sustainability approaches in remediation projects; Sustainable remediation using renewable energy; and Sustainable remediation using phyto-techniques. Table 1 lists the presentations in each session, and these are summarised in Chapter 3. Overall meeting conclusions are summarised in Chapter 4.
## 1.2 Workshop contents

### Development of sustainability frameworks

- The Common Forum-NICOLE joint position statement on sustainable remediation; Dominiqvee Darmendrail (France Common Forum Secretary) and Lucy Wiltshire (Honeywell – United Kingdom & NICOLE member) – 2.1*
- Development of practical guidance to promote sustainability considerations in land contamination management in the UK; Brian Bone (SuRF-UK Steering Group – United Kingdom) – 2.2
- Flanders implements green and sustainable remediation by a threefold approach; Griet van Gestel (OVAM – Flanders, Belgium) 2.3
- Integrating sustainable development principles into Shell’s global soil and groundwater management program; Jonathan Smith (Shell Global Solutions – Netherlands/United Kingdom)
- Use of SURF-UK indicators to evaluate remediation alternatives in Northern Ireland; James Day and David Ellis (CH2M – Germany / DuPont – United States of America)
- Optimizing remediation sustainability using a two-step stochastic method; Gary Wealthall (Geosyntec Consultants – Canada)
- Syndial approach to sustainable remediation - an Italian case study; Emanuela Gallo, Giorgio Bianchi and Luciano Zaninetta (Syndial – Italy)

### Implementing sustainability approaches in remediation projects

- Field development of 'in situ reactive zone' (IRZ) for the sustainable treatment of Chromite ore processing residues (Copr) Heap; Thomas WohlhaIter (Arcadis – France) - 3.1
- Life cycle assessment of soils and groundwater remediation with zero valent iron nanoparticles: Results from a pilot study in Barreiro, Portugal; - by Helena Gomes and Celeste Jorge (CENSE (Center for Environmental and Sustainability Research) – Portugal) - 3.2
- Mulch biowalls as low cost sustainable remediation for contaminated soils and groundwater; Kevin Morris (ERM – United States of America)
- Optimizing the remediation solution for a complex solvent plume, following the NICOLE road map; Tracy Braithwaite (AWE – United Kingdom) and Matthew Pearce (WorleyParsons – United Kingdom)
- Sustainability assessment of the redevelopment of Hexion with CEEQUAL; Petra Brinkhoff (NCC Construction – Sweden)
- Sustainability assessment of remedial options for a former oil terminal site; Richard Bewley and Emily Ghedia (URS Infrastructure & Environment – United Kingdom)
- Overcoming barriers to effective phyto-management of contaminated land – the GREENLAND project; by Nele Witters (University of Hasselt – Belgium) – 3.17

### Sustainable remediation using renewable energy

- Green soil remediation projects at the Bilthoven and Amersfoort sites; Johan van Leeuwen (SBNS – Netherlands) – 4.1
- Parys Mountain metal mine, Anglesey, Wales: Sustainability in mine water remediation; Rick Parkman (URS Infrastructure & Environment – United Kingdom) – 4.2

### Sustainable remediation using phyto-techniques

- Engineered phytoremediation at an industrial site contaminated with aromatic hydrocarbons; Frank Volkering (Tauw – Netherlands / Dow – Netherlands) - 3.16
- Overcoming barriers to effective phyto-management of contaminated land – the GREENLAND project; by Nele Witters (University of Hasselt – Belgium) – 3.17

*codes refer to section where the corresponding presentation summary can be found.
2. Session 2: Development of sustainability frameworks - 1

Session Chair: Peter Wouter – ENVIRON, Spain

Sustainable Remediation

Two key aims of sustainable remediation are:

1. To gain a net benefit (environmental, economic and/or social) from the chosen remediation option and;
2. To obtain a balanced outcome through incorporation of risk based land management, consideration of the acceptability of the remediation technique’s wider impacts, and the inclusion of stakeholder participation.

Sustainable remediation concepts are broadly based on the achievement of a net benefit overall across a range of environmental, economic and social concerns that are judged to be representative of sustainability. However, what “sustainability” encompasses is highly site specific and is dependent on the opinions of a range of stakeholders with interests in a particular site. As such, sustainability is not objectively quantifiable.

On a site specific basis, however, it is possible to assess sustainability, compare possible remediation options, and monitor/ improve sustainability “performance” as a chosen option is implemented. This emerging shared understanding worldwide is both significant and beneficial, and has been supported by excellent interaction and collaboration.

Success Factors

The reason for carrying out remediation is to manage unacceptable risks, caused by soil contamination, for human health and the environment. Sustainable remediation seeks the optimum way to manage these risks, typically taking into account environmental as well as economic and social factors. Several initiatives, including NICOLE and SuRF, emphasise the importance of considering sustainable remediation early in decision-making when design decisions are being made that set the boundaries for risk management. An example framework for sustainable remediation decision making is provided by SuRF-UK, as shown in Figure 1 below.

Incorporating sustainability early in decision making can deliver substantial gains in level of sustainability attained. Figure 2 shows how sustainability gains are dependent on the stage of the project during which sustainability is introduced.

Other important features of a successful sustainability assessment include:

- Simplicity
  - Taking a tiered approach (qualitative → semi-quantitative → quantitative)
  - Stopping when there is sufficient information to make an effective decision
- Stakeholder involvement
  - Inclusiveness
  - Transparent reporting

Early stakeholder involvement is key to persuasive approaches to sustainability assessment, as stakeholders are unlikely to agree to something presented as an output from a “black box” or an assessment whose basis they fundamentally disagree with.
Figure 1 – SuRF-UK Framework for Sustainable Remediation Decision Making

Figure 2 – Sustainability Gains Relative to Introduction Stage: Green Remediation and Green Remediation
Techniques vs. Sustainable Remediation

A related term to sustainable remediation, “green remediation”, refers to a specific concept developed by the US EPA. It is the attempt to achieve an improvement in the broad environmental performance of remediation and applies to a regulatory framework where the socio-economic context and risk management objectives have already been set by previous decision making. The US EPA has developed detailed guidance on implementation of green remediation and environmental footprinting. The regulator in Flanders, OVAM, is adopting a similar approach to green remediation for remedy assessment in its BATNEEC tool. However, OVAM is also looking at sustainable remediation.

“Green” and “sustainable” remediation share some common elements. For example, the US EPA green remediation considerations have a fairly close match to the SuRF-UK environmental segment. However, sustainable remediation also considers the social and economic implications and benefits of remediation. It should be noted that a delineation is made between green remediation and green remediation techniques. Green remediation techniques typically involve low input and low impact techniques; this is not the same thing as the US EPA defined term of green remediation. Green remediation techniques can also be referred to by the EC FP7 Greenland Project term of “gentle remediation options” (GRO).

GRO are risk management techniques for contaminated sites that result in no gross reduction in soil functionality / soil ecosystem services (or a net gain) as well as risk management. GRO may be suitable for large areas and soft end uses (i.e. where a functioning soil is required), as soil typically remains biologically productive. Sustainability interests and stakeholder engagement in these cases can be wide ranging and complex.

International Development of Sustainable Remediation

Sustainable remediation could now be regarded as a global phenomenon, with initiatives such as SuRF having contingents worldwide. Numerous projects, standards and networks exist or are being instigated internationally to help the development of sustainable remediation. In aid of this, there are various instances of networks working in conjunction with projects, for example, the joint secretariat hosted by CL:AIRE and specific initiatives such as the International White Paper initiated by SuRF.

Ongoing Debates, NICOLE Support Documents

In terms of the current stance of sustainable remediation, it is clear that remarkable progress has been made, with open exchanges occurring at an international level. Nonetheless, a number of debates are still on-going. For example, “how do we deal with subjectivity?” and when/how to apply risk based vs. sustainability based decision making paradigms. To aid sustainable remediation decision making, NICOLE has published a Road Map and associated Guidance Documents. The Road Map is intended to provide problem-holders (owners/operators of contaminated land) and all stakeholders, with a single, structured process to start implementing best practice in sustainable remediation across a wide range of regulatory and policy frameworks. Designed as a series of steps to ensure a consistent and collaborative approach to decision-making, it can support robust and durable decisions, regardless of the project size.

References

NICOLE (2011) Road map for sustainable remediation. www.nicole.org

www.zerobrownfields.eu

www.greenland-project.eu
2.1 The Common Forum - NICOLE Joint Position Paper on Sustainable Remediation

Presenters: Dominique Darmendrail (Common Forum on Contaminated Land in Europe, France) and Lucy Wiltshire (Honeywell, UK)

Presentation Outline

1. Introduction
   The Common Forum on Contaminated Land in Europe Mission

2. Why a Joint Position Statement (JPS)?
3. Context of JPS development
4. SR Key Messages
5. Dissemination of ideas
6. Further info

Presentation Summary

The Common Forum on Contaminated Land in Europe began in 1994 and is a network of contaminated land policy and regulator experts. Its mission is to provide a platform for knowledge exchange and discussion on policy, research and managerial concepts of contaminated land. It aims to initiate and continue international projects and offer expertise exchange between the European Commission, Member States and European Networks such as NICOLE.

A Joint Position Statement has been proposed to define and highlight the shared key concepts of sustainable remediation (SR) and encourage a broader utilisation of SR across Europe. The key concepts of SR, based on the work from CLARINET and other international networks to encourage good practice include:

- Protection of human health and the environment
- Maximise overall benefit of remediation through a transparent decision-making process
- Contribution to sustainable development
- Efficient use of socioeconomic resources for enhanced land management and remediation
- The crucial Stakeholder engagement
- Sustainability incorporated as early as possible

Dissemination of ideas will be achieved via national and international networks, utilisation of media opportunities and targeted publications. Translations in several European Official languages are provided (English, French, German, Spanish, Italian and Dutch).

References

www.commonforum.eu

www.nicole.org
2.2 Development of Practical Guidance to Promote Sustainability Considerations in Land Contamination Management in the UK

Presenter: Dr Brian Bone (Bone Environmental Consultant Ltd.) representing the SuRF-UK Steering Group

Presentation Outline

1. Background
   Legislative context for sustainable remediation in the UK

2. The UK Sustainable Remediation Forum (SuRF-UK)
   Objectives of current work (Phase 3)

   Definitions and context
   Mapping BMPs to sustainability indicators
   Practical examples of how BMPs may be used

4. Tier 1 Briefcase
   Project framing and planning
   Overview of briefcase

5. Summary and conclusions

Presentation Summary

The UK Sustainable Remediation Forum (SuRF-UK) was established in 2007 to support the application of sustainability principles for remediation in the UK. It is a collaborative, multi-stakeholder initiative coordinated by CL:AIRE with a Steering Group that incorporates members from regulatory bodies, industry, consultancy and academia. SuRF-UK initially focussed effort on developing the first formal framework for assessing the sustainability of remediation strategies in 2010 that was fully supported by UK government and national regulatory bodies (CL:AIRE 2010). A second phase of work focussed on disseminating the framework widely through conferences, webinars and a peer-reviewed paper (Bardos et al. 2011) and on refining the sustainability indicator sets used within the framework through a series of stakeholder workshops (CL:AIRE 2011).

The SuRF-UK framework has received an enthusiastic welcome and is used mainly by larger consultancies and problem holders. To encourage wider use a third phase of work started at the end of 2012. This phase is focussing on compiling case studies and providing practical guidance on carrying out relatively simple, qualitative assessment. This guidance is in two parts.
The first part is the development of Best Management Practices aligned to the SuRF-UK sustainability indicator categories so that the same sustainability principles underpin all aspects of land contamination management and can be applied across the full range of activities, including those that would not normally have a formal sustainability appraisal. An example of how BMPs may be considered is presented; taken through tendering, planning and carrying out a site investigation. Figure 3, below, shows the SuRF-UK BMP process.

![SuRF UK BMP Process]

The second part is an assessor’s aid to carrying out a qualitative sustainability appraisal. A range of potential methods are offered for the more complex (semi-)quantitative approaches (e.g. Multi-Criteria Analysis, Cost-Benefit Analysis), but not for the simpler qualitative appraisals, which SuRF-UK recommend as a starting point. The assessor’s aid fills this gap in guidance and may be used by the assessor as a refresher, as a training tool or even to help guide a stakeholder group through the sustainability appraisal process. SuRF-UK expect this ‘sustainability assessor pack’ for qualitative appraisals to encourage wider use of the SuRF-UK framework by small to medium-sized environmental consultancies and their clients.

Tier 1 assessment is addressed as the “entry level” sustainability assessment. Tier 1 is broadly qualitative and based on simple tables of qualitative categories, e.g. “good” or “better”. Tier 1 is seen as lower effort, however, it still requires that sufficient framing and planning for the assessment has been carried out in advance. A “briefcase” (shown in Figure 4) is presented as a tool for the execution of Tier 1 sustainable remediation assessment with the relevant stakeholder group. The “briefcase” provides a step-by-step framework for assessment, providing checklists and templates to ensure complete activities and full recording and justification of actions.
Figure 4 – Tier 1 "Briefcase" Assessment Tool

<table>
<thead>
<tr>
<th>Option 1</th>
<th>Option 2</th>
</tr>
</thead>
<tbody>
<tr>
<td>Environment</td>
<td>Better</td>
</tr>
<tr>
<td>Society</td>
<td>Equal</td>
</tr>
<tr>
<td>Economics</td>
<td>Worse</td>
</tr>
</tbody>
</table>

References


2.3 Flanders Implements Green and Sustainable Remediation by a Threefold Approach

Presenter: Griet Van Gestel, OVAM

Presentation Outline

1. Introduction – OVAM
2. Guidelines and tools for assessment of sustainable remediation
   Benefits of guidelines
   Stakeholder workshop (2011) – focus on global and long-term effects
   Development of a new MCA for assessing green remediation
3. Co-financing pilot projects for green and sustainable remediation
   Aims and overview
   Pilot studies – phytoremediation and combination ATES and groundwater remediation
   Third call for pilot studies
4. Setting the example for ex officio soil remediation projects
   Soil remediation maximally integrated into site redevelopment
   Communication with local communities
   Green specifications for contractors

Presentation Summary

OVAM (Public Waste Agency of Flanders) promotes green sustainable remediation. This is achieved through:

1. Provision of guidelines and tools for green and sustainable remediation assessment
2. Co-financing pilot projects for green and sustainable remediation
3. Setting the example for ex officio soil remediation projects

Guidelines improve sustainable remediation assessment through ensuring objectivity and transparency. Presently, soil remediation techniques are chosen according to BATNEEC principle, with an emphasis on removing local risks and reducing residual contamination. To assess green remediation, a new multi-criteria analysis (MCA) and CO₂ calculator was developed. This was adapted to take into account global warming (introduction of CO₂ calculator) and sensible use of energy and materials (criterion on production of non-recyclable waste). The new MCA was developed based on literature studies and recommendations to change the present BATNEEC evaluation. Following this, a feasibility study was carried out by Tauw (2012) and a meeting with stakeholders was held, with a focus on global and long-term effects. Implementation of the new MCA is intended to be gradual, with steady introduction into good codes of practice. An assessment tool for sustainable remediation is under way. Further, SURF-UK indicators were evaluated for their potential adaptation in Flanders. Conclusions drawn from the new MCA development were that communication and participation can be improved and soil remediation could be integrated with spatial planning.

To further green and sustainable remediation, innovation is needed. To this end, OVAM co-finances pilot projects to gain more insight and demonstrate and disseminate knowledge. Pilot studies are presented, including a phytoremediation project in association with Arcadis and University Hasselt. This project involved
the use of poplars to remediate contaminated groundwater. An additional pilot study utilised ATES in combination with groundwater remediation.

A series of principles sees OVAM setting an example for ex officio soil remediation projects:

- Maximal integration of soil remediation with site redevelopment
- Emphasis on communication with local communities
- “Green” specifications for contractors working on soil remediation projects
3. Session 3 – Implementing sustainability approaches in remediation projects – 1

Session Chair: Oliver Phipps – ERM, United Kingdom

3.1 Field Development of In Situ Reactive Zone (IRZ) for the Sustainable Treatment of Chromite Ore Processing Residues (COPR) Heap

Presenters: Thomas Wohlhunter (Arcadis); Co-Authors: Thierry Gisbert, Ludovic Ferriere & Jean-Louis Mauss

Presentation Outline

1. Introduction
   Implementation of Sustainability in Management of Contaminated Land
   The PCUK area and the COPR heap

2. Initial Site Conditions and First Works
3. In-situ Reactive Zone technique
4. How to convince stakeholders: lab to field
5. IRZ technique as a sustainable solution

Presentation Summary

Anaerobic IRZ has been selected as the relevant remedial technique for a former Chromium Ore Processing Residues (COPR) landfill, located in the northern part of France. This former landfill site has been used since the beginning of the 20th century by several industrial companies. The ore residues, containing chromium VI (average 30g/kg), have been stored as long as the activity occurred and form what is now called the “Grand Terril”. Until 2011 and after several phases of remediation, between 15 and 20 m³ of leachate were collected daily from the base of the heap. This alkaline leachate, which contains elevated loads of Cr⁶⁺ (200-1200 mg/l), a toxic compound, was pumped in order to maintain confinement of the chromium plume within the site area and processed in an external treatment plant (2 to 5 trucks per week).

It has been estimated than the time required to reach the target groundwater concentration by pumping and treating the effluent was one to three hundred years; this treatment was not a sustainable solution. This expensive and carbon dioxide emitting treatment was stopped when landfill remediation work started (summer 2011). It was replaced by a more sustainable treatment which uses waste from the sugar production industry (molasses). This treatment is low energy; gravity is used and the only electricity required is for pumps and mixing equipment. There is no external water treatment and no thermal equipment.

IRZ, the In Situ Reactive Zone technique, is a biological treatment based on anaerobic bio-precipitation under reductive conditions, applicable to metals. Its main aim is the creation of a subsurface redox environment (adding carbohydrates) where conditions are modified in order to enhance natural processes: migrating contaminants are intercepted and permanently immobilized. Figure 11 shows a conceptual scheme for IRZ. This treatment is expected to last 4 to 8 years, depending of the response of the milieu to the treatment.
One of the major difficulties at this site was to demonstrate the feasibility of the chromium precipitation on these residues, first at lab scale, then on site. Indeed, it was the first time in Europe that this remedial technique was selected to treat high concentrations of metals (>4 g/L), in a very basic milieu (pH: 12 to 14), where conditions were not favourable for bacterial growth. Demonstrating the technical feasibility of this in-situ treatment helped to convince SOLVAY DRE, the local environmental authority, the public funding organisation for land redevelopment, and the local municipalities of the merits of this approach. However, it took almost 10 years from initial concept to implementation due to requirement of convincing stakeholders.

Additionally, these pilot steps allowed gathering and adapting of different technologies already used in other technical fields (geotechnical issues for drilling operations, effluent recirculation as developed for anaerobic bioreactors in municipal solid waste landfills, contaminated site remediation equipment, microbiological analysis, etc.) Following this, the site was equipped with various injections systems in order to carry out full size treatment: wells and trenches (short or long), to treat both the vadose zone and the saturated one.

After almost 18 months of treatment, the areas where molasses (carbohydrate source) were injected show good responses in some monitoring wells; chromium concentrations have started to drop. Figure 12 shows how IRZ can be viewed as a sustainable solution, taking into account environmental, societal and economic issues. Overall, it is concluded that IRZ is more cost and time effective and has an “infinite lifetime” compared to other solutions.
Figure 12 – Summary of Sustainable Elements of IRZ
3.2 Life cycle assessment of soils and groundwater remediation with zero valent iron nanoparticles: Results from a pilot study in Barreiro, Portugal

Presenters: Helena Gomes & Celeste Jorge (CENSE); Co-Authors: Jorge Goncalves, Celia Dias-Ferreira, Alexandra B. Ribeiro

Presentation Summary

A pilot test using zero valent iron nanoparticles (nZVI) was performed in a brownfield in Barreiro, southeast of Lisbon, Portugal, by the consortium GEOPLANO/LNEC (private company and the National Laboratory of Civil Engineering), between December 2010 and November 2011. The current work also involves two research centres in Portugal: the New University of Lisbon and the Polytechnic Institute of Coimbra.

A life cycle assessment (LCA) was performed, based on the International Reference Life Cycle Data System (ILCD) Handbook and using the software SimaPro to compare the environmental impacts of two different remediation alternatives: excavation and landfill versus remediation using nanoparticles. To undertake the LCA, the main challenge was to collect data to perform a comprehensive assessment. Different sources were considered, from the nZVI manufacturer, the pilot study and other information available in the literature. Another important issue was to determine the environmental impacts of the nZVI post remediation and to assess ecological risks, health risks and social acceptability of this emergent remediation technology.

3.3 Mulch Biowalls as Low Cost Sustainable Remediation for Contaminated Soils and Groundwater

Presenter: Kevin A. Morris (ERM)

Presentation Outline

1. Introduction and overview
2. Remediation selection – process & considerations
3. Mulch biowalls/bioreactors
   - Why Mulch?
4. Applications
5. Green and sustainable remediation
6. Case studies
7. Conclusion

Presentation Summary

Mulch biowalls are considered a viable, long-lasting, low environmental footprint alternative as an in situ groundwater remediation technology for the treatment of chlorinated solvents, perchlorate and other recalcitrant compounds that are amenable to anaerobic reduction processes, but have found limited application in Europe. Wood mulch provides a sustainable carbon source to stimulate indigenous microbes to generate reducing conditions and degrade contaminants to innocuous end products. Mulch can be generated on site or obtained locally at a fraction of the cost of other substrates. This case study presents the results from three mulch biowalls installed at two different industrial sites in the continental United States in 2003 to
address Chlorinated Volatile Organic Compounds (CVOCs) and perchlorate contamination in soils and groundwater.

Prior to selecting mulch biowalls, a desktop feasibility analysis was conducted that included other remediation technologies such as; pump and treat, multi-phase extraction and thermal. One of the trenches was installed as a 6 metre-deep infiltration trench connected to shallow collection trenches that divert storm water into a retention pond. The infiltration trench was designed and constructed to treat perchlorate-impacted shallow clayey soils at 1.5 to 4.5 m below ground surface (bgs) and shallow groundwater (2.4 to 5.4 m bgs), by initiating an anaerobic treatment zone to stimulate the indigenous bacteria to degrade perchlorate in both soil and water matrices. The laboratory data has shown a reduction of perchlorate in the shallow soils from approximately 85 mg/kg to less than 1 mg/kg in the 10-year operation of the system, in groundwater by over 90% and a reduction in surface water of 99%.

Two trenches were installed at the other industrial site, 90m apart as barrier trenches to intercept CVOC and perchlorate impacted groundwater prior to discharging to a small intermittent stream and immediately downgradient of a CVOC and perchlorate source area. The dimensions of the trenches are approximately 60 m long by 3.6 to 4.5 m deep and backfilled with a 50/50 mix of local mulch and gravel. The upgradient trench is connected to a groundwater recirculation system to increase the treatment zone length parallel to groundwater flow. Laboratory data continues to indicate reductions of both CVOCs and perchlorate in groundwater of 90 and 99%, respectively at the most downgradient monitoring well. Laboratory data collected from the surface water of the intermittent stream indicates that the stream is benefiting from the reductions in the residual contaminants in the shallow groundwater. Total CVOCs have been reduced from a high of 36 µg/L in May 2002 to non-detect for the last three quarterly sampling events while perchlorate has also reduced from a high of 109 µg/L in November 2001 to non-detect.

In addition to the technical performance of the mulch walls described above, the technology in the context of wider sustainability issues including experiences with respect to environmental, economic and social indicators is considered. Construction and operational data collected during the course of this study has also been used to estimate the environmental footprint of these technologies and the presentation of this data forms a useful resource for the future evaluation of mulch walls as a remedial technique.
4. Session 4: Sustainable remediation using renewable energy

Session chair: Philippe Menoud – Dupont, Switzerland

4.1 Green Soil Remediation Projects at the Bilthoven and Amersfoort Sites

Presenter: Johan van Leeuwen (Stichting Bodemsanering NS, Netherlands)

Presentation Outline

1. Introduction
2. Bilthoven site - engineering, design and installation
3. Animation
4. Results
5. Amersfoort site - engineering & design
6. Conclusions

Presentation Summary

An SBNS initiative to implement sustainable /green elements into soil remediation activities resulted in two green in-situ project sites: Bilthoven and Amersfoort. Bilthoven has been operational for one year, whilst Amersfoort is under installation. Both sites feature renewable energy as the only energy source for remediation works.

The Bilthoven project started in 2011 as part of a larger project building two tunnels under a railroad. At this site, the saturated zone is contaminated with petroleum hydrocarbons (diesel). The groundwater component target level is 600μg/l for mineral oil. This innovative project is executed in cooperation with consultancy Tauw and contractor HMVT.

Initial engineering discussions lead to several feasible ideas including:

- Solar soil heating to enhance bioremediation
- Windturbine for compressed air production: the generated compressed air is injected into the soil with microsparge filters to support biodegradation processes.
- Solar power for operating small pumps and telemetric system. Electricity is generated by PV-cells
- Wind power for soil vapor extraction. A chimney is erected and with the use of under pressure so soil vapors are extracted

Initial results showed an increase in temperature by more than 4 degrees centigrade after 20 weeks. After 1 year, up to 100% reduction was seen in mineral oil contamination on the site.

The Amersfoort site was excavated in 2007 and treated via pump and treat between 2008 and 2012. At this site, the saturated zone of the soil is contaminated with chlorinated solvents PCE and TCE. Groundwater needs to be remediated to a maximum level of 0.5 and 6.0 μg/l respectively. Pump and treat was not considered cost efficient however remediation of the site was still required.

“Green” pump and treat is being installed on this site where wind power will be used for pumping contaminated groundwater to the surface, where it will be passed through a constructed wetland for bacterial
water treatment (See Figure 20). TCE and PCE will be reduced by bacterial attenuation in the constructed wetland.

4.2 Parys Mountain Metal Mine, Anglesey, Wales: Sustainability in Mine Water Remediation

Presenter: Rick Parkman (URS Infrastructure & Environment, United Kingdom); Co-Authors: R. Parkman, S. Pearce, R. Knott & P. Goodman

Presentation Summary

The now abandoned Parys Mountain metal mine complex was mined since the Bronze age, 3500 years ago. During the C18th/C19th the site was the largest exporter of copper globally. The last mining occurred in the early part of the C20th, although site exploration continues today to identify additional mineral reserves that are economically viable for recovery as global commodity prices continue to rise. The environmental legacy extends from the residual un-mined metal sulphide minerals (i.e. pyrite, chalcopryite and arsenopyrite) which oxidise and hydrolyse (in reaction with oxygen and water) to release heavy metals and sulphuric acid. The production of sulphuric acid with little buffering capacity from the host geology creates a very low pH discharge (c. pH 1.5-2) with very high metalliferous loadings. Untreated mine water drains from the historic workings at Dyffryn Adda Adit, and flows into the Afon Goch stream which flows through the town of Amlwch before discharging into the Irish Sea, with significant environmental (and social) impacts throughout this flow
path. The discharge is being regulated under the Water Framework Directive (WFD). Since 2011, URS has been working with Environment Agency Wales (EAW) to undertake feasibility studies, remediation optioneering and stakeholder consultation looking towards practical implementation of a sustainable solution. The three core principles of sustainability are the key drivers for treatment of the discharge:

**Environmental:** The site is the most significant single discharge of metals to UK coastal waters including both hazardous and priority hazardous substances (i.e. cadmium). EAW is required to satisfy the conditions of the WFD for the Afon Goch and Irish Sea

**Social:** Significant stakeholder pressures need to be accommodated in deriving an appropriate remedial solution including; the local council, residents, impacted landowners, heritage/ academics groups (the mine site is a Site of Special Scientific and Biological Interest)

**Economic:** Desire to drive down CAPEX and OPEX costs via innovation/ sustainable measures. The poor quality of the mine water discharge meant that passive treatment (i.e. treatment wetlands) ‘green remediation’ was not suitable, and thus active treatment (i.e. energy and resource intensive) was required. URS sought to drive sustainability/ cost efficiency through our decision-making and technology selection process:

**Treatment Method Selection:** Through URS’s UK/ global resource we researched the best available techniques in terms of resource consumption (i.e. alkali reagents) and volume of waste sludge produced requiring disposal. This process of internal collaboration informed the selected long-list of options and drove sustainability issues throughout. Treatment techniques were considered which have never been used before in the UK, diverting from traditionally employed and potentially less sustainable methods (e.g. alkali/lime dosing followed by landfilling).

**Stakeholder Engagement:** The main project issues/ difficulties arose through diverging stakeholder interests and opinions which were essential to acknowledge in order that each key stakeholder felt that their opinion was valued and had been considered. A bespoke stakeholder engagement strategy was developed. The long-list of remediation options was presented at a stakeholder engagement workshop, discussed at one-to-one meetings and communicated through mail-shots to refine the treatment selection concepts. This included discussions of: treatment location (nuisance and landtake), degree of remediation considered acceptable/appropriate to different groups, integration with local history/ heritage/ academic groups to benefit the wider community; before making a final recommendation to EAW as a short-list with URS’ single preferred option. URS stakeholder engagement strategy was commended by EAW.

**Energy/ Eco-efficiency:** URS proposed the use of renewables such as geothermal energy/ wind generation to power site equipment for the treatment plant to reduce OPEX and environmental footprint. The use of geothermal energy from mine waters to power plant is a novel solution. The Parys Mountain Metal Mine Project demonstrates excellence through all of core elements of sustainability through driving innovation, environmental benefit, eco-efficiency and through considerable stakeholder consultation to refine the remedial alternative selection. Our approach to this case study will be presented with reference to the NICOLE Roadmap and other similar approaches for Sustainable Remediation (e.g. SURF UK).
5. Session 5: Implementing sustainability approaches in remediation projects – 2

Session chair: Hans-Peter Koschitzky – University of Stuttgart, Germany

5.1 Optimizing the Remediation Solution for a Complex Solvent Plume, Following the NICOLE Road Map

Presenter: Matthew Pearce (Worley-Parsons, UK); Co-Authors: Tracy Braithwaite, Mike Loxley, Helen Matheson, & Clive Rivers.

Presentation Outline

1. Background
   Conceptual model

2. Objective and options

3. Data, assumptions and parameters
   Main data sources
   Modelling parameters (assessment and financial)
   Key assumptions
   Capital expenditure breakdown

4. Valuations
   Summary of externality valuation
   Carbon dioxide
   Traffic Impacts
   Groundwater
   Ecology of Fishing Ponds
   Amenity of Fishing Ponds

5. Results
   PV Breakdown
   NPV
   Marginal analysis
   Sensitivity analysis

6. Conclusions
Presentation Summary

WorleyParsons carried out a Sustainability Analysis/EcoNomics™ Assessment with the aim of considering a wide range of risk mitigation options and identifying the most sustainable approach for mitigating potential risks from a historical solvent release.

The assessed site is located in South-East England and is a large industrial complex which has been present since the mid-20th century and is likely to remain in its current use for at least the next 50 years. A conceptual model for the site is shown in Figure 13. The primary source zone is a former solvent evaporation pit, which has historically released contamination to groundwater. Remediation was previously carried out within the source zone. Significant contaminant mass was removed from the sub-surface, however, residual contamination continues to present a potentially significant risk to groundwater and surface water. A decision had to be made on whether to restart the existing system, apply alternative approaches or whether a more sustainable optimised remediation solution was available.

Figure 13 – Conceptual Site Model

The site is designated as Contaminated Land under Part 2A of the UK Environmental Protection Act 1990. Therefore, there is a history of regulatory involvement with the Environment Agency in the site management. WorleyParsons worked in accordance with the Nicole sustainability road map, involving numerous members of the client’s team and regulators throughout the process in agreeing the objective, approach, boundaries and assets of value to be considered in the assessment. During the framing workshop, stakeholders were brought together to consider the objective and the scope of the assessment. In a collaborative and iterative process, the objective of the assessment was determined to be to identify the most socially, environmentally and financially acceptable longterm solution for the client that would also get support of the regulator.

A shortlist of potential management options, including large scale engineering/remediation solutions, small scale pathway interruption, to business as usual. The social, environmental and financial benefits and dis-benefits for each option were identified and quantified. Detailed research was carried out by economists to develop social and environmental valuations for such assets as surface water, groundwater and sensitive ecology.
In addition, economic studies of external impacts for such activities as HGV movements, and CO₂ emissions were reviewed to allow financial valuations to be applied. Combined with engineering data collection, including high level remedial estimates, this information was input into the WorleyParsons EcoNomics™ modeling tool. The EcoNomics™ as part of the sustainable remediation decision process is shown in Figure 14. The most sustainable option was identified as pathway interruption through backfilling of an ephemeral pond and upgrading the storm drainage system which has been acting as a preferential pathway. This approach was not the cheapest option available as part of this assessment, but provided a substantial saving over costs for options which had previously been considered. It also provided a substantial reduction in waste, emissions, HGV movements, over other options, whilst resulting in similar benefits to amenity and ecology in the local country park.

![EcoNomics™ as Part of Sustainable Remediation Decision Making](image)

The results of the EcoNomics™ Assessment were used as a communication tool to support the client in presenting their recommended management option to the regulator, ensuring that proposed expenditure was balanced by added value to both society and the environment. Regulator acceptance of this approach was achieved easily in a single meeting, and the client intends to progress this approach.
5.2 Sustainability Assessment of the Redevelopment of Hexion with CEEQUAL

Presenter: Petra Brinkhoff (NCC Construction, Sweden); Co-authors: Kristine Ek & Malin Norin

Presentation Outline

1. Introduction
2. Construction companies and remediation
   - Sustainability & sustainable development
   - Sustainability in construction projects
   - Views on sustainable remediation
3. CEEQUAL
   - CEEQUAL and sustainability
4. Case Study
   - SCORE project
   - Hexion redevelopment
5. Assessment Results
6. Functionality of CEEQUAL

Presentation Summary

The civil engineering sector implies both positive and negative effects on people and the environment. In respect to greenhouse gas emissions the civil engineering sector stands for a substantial contribution each year. It is desirable, from the authorities as well as from the industry itself, that necessary infrastructure and housing projects have as small negative effects as possible. There is an on-going discussion within the industry about how these type of projects can be performed in a more environmentally friendly and sustainable manner. The same discussion exists among remediation experts as remediation projects often have the same basic goal as other land and construction projects; a measure is necessary. Hence a method to evaluate impacts of civil engineering projects including remediation is desirable. CEEQUAL is a sustainability assessment tool usable for these types of evaluations. How CEEQUAL functions is shown in Figure 15. CEEQUAL has been used in 130 projects around the world and is one of the few available tools on the market. CEEQUAL focuses on two of the three domains of sustainability: the environmental and the societal (See Figure 16). CEEQUAL's goal is to make sustainability issues visible and workable in projects at an early stage and hence give opportunities to deliver a more sustainable project than if only the legal requirements were strictly followed.
Figure 15 – Stages Involved in the CEEQUAL Process

Figure 16 – CEEQUAL and Sustainability
CEEQUAL has been used in a remediation project in Mölndal, near Gothenburg in Sweden (Hexion site). Figures 17 and 18 show the site prior to demolition and the envisaged new use respectively. The assessment was performed after the actual remediation had taken place i.e. ex post. The property, purchased by NCC, is a former industrial site where activities, e.g. paint manufacturing, have left behind contaminants such as phthalates, lead and aliphatic hydrocarbons. Future land-use plans include a residential area, hence remediation was needed. The selected remediation alternatives for Hexion were excavation, sorting by sieving and transportation of contaminated material to a nearby landfill. This was decided based on impacts and risks to neighbours and the environment, feasibility studies and stakeholder communication.

Figure 17 – Hexion Prior to Demolition
The redevelopment of the property is an in-house project where NCC is responsible for the whole project including the CEEQUAL assessment. External stakeholders were, among others: the County Administrative Board of Västra Götaland, Mölndal municipality, other consultants and neighbours. The assessment result shows that excavation in combination with sieving (to minimise transports to off-site disposal) were effective from an economic and social point of view. The use of Multi-criteria Analysis and Life Cycle Assessment to evaluate the sustainability of different remediation alternatives had a great influence on the final grade given by CEEQUAL since it demonstrated that sustainability issues were illuminated before a decision on remediation alternative was taken.

After completion, the functionality of CEEQUAL was evaluated. Key positives included that it provides a comprehensive picture environmental impacts, enables more sustainable engineering by influencing project design and allows clients to incorporate sustainability issues early in the construction process, prior to major decision making.

5.3 Sustainability assessment of remedial options for a former oil terminal site

Presenter: Richard Bewley and Emily Ghedia (URS Infrastructure & Environment, UK)

Presentation Outline

1. Overview
2. Background and context of site
   Objective of study
   Conceptual site model and risk assessment
3. Assessment process
Initial collation of relevant site and project data

Workshop attended by the project team

Collation of additional data required to complete the assessment and development of options

Completion of the assessment

Reporting

4. Application of URS tool
5. Results and conclusions

Presentation Summary

A case study is presented of a sustainability assessment of remedial options at a former oil terminal site on the island of Madeira from the perspective of the client. The decision making process that was used to determine the boundaries of the assessment, the agreement of remedial options, the relevant assessment criteria with associated weightings within the context of alternative end use scenarios, and the methodology that was brought to bear, particularly in the context of the NICOLE Roadmap are all set out. The process followed can be seen in Figure 19. The findings of the assessment are discussed, together with lessons learned.
The case study site operated for around 45 years before being demolished in 2007, when a redevelopment plan was agreed with relevant stakeholders. Excavation and thermal treatment was favoured as the preferred remedial approach. Due to the economic downturn, the redevelopment plan was suspended. The removal of time constraints presented the opportunity for a review of alternative and potentially more sustainable technologies.

The first task involved summarising business objectives, identifying relevant stakeholders and collating relevant site data. Stakeholders included the client, the consultant, the local government, Madeira Regional Environment Agency, surrounding neighbours and the purchaser.

This was followed by a workshop that established the boundaries of the assessment, considered stakeholder views, agreed upon remedial options, relevant categories of indicators for economic, environmental and social aspects, together with their associated weighting, identified end use scenarios and finally determined the nature of the sustainability assessment itself. The assessment focused upon five ex situ approaches, these being thermal desorption; land farming, enhanced bioremediation, soil washing, and excavation and disposal. The relevant criteria for the assessment comprised (i) economic: direct economic costs and benefits, project lifespan and flexibility; (ii) environmental: impacts on air, natural resources and waste; (iii) social: human health and safety, neighbourhood and locality, compliance uncertainty and evidence. The justification and key relevant indicators for each of these criteria will be discussed. Various scenarios based on a requirement either to complete within 18 months or within 5 years were considered, based on redevelopment (i) for unrestricted end use (most onerous remedial criteria) (ii) in line with the existing site master plan, or (iii) according to an updated site master plan where the end use zoning of the site took some account of the degree of contamination present (least onerous remedial criteria).
The unrestricted end use was rejected following a review, so that the assessment was taken forward on the basis of four scenarios: these being two end uses, with and without the time constraints. An innovative in house three tiered model was used to assess the sustainability of each of the five options based on the assessment criteria and according to each of the four scenarios. A Tier 1 (semi-quantitative) assessment was performed, which takes a holistic view of the various sustainability indicators and assigns a score to the relevant assessment criteria that had been weighted accordingly at the workshop. The findings of the assessment indicate that enhanced bioremediation was the most sustainable remedial approach representing a change from the original remedial strategy. As the original time constraints were no longer applicable, an alternative more sustainable solution was found. The assessment highlighted specific indicators that should be addressed in detailed implementation planning for an enhanced bioremediation approach (e.g. potential dust and odour issues). Uncertainties were identified.
Session Chair: Elise Noel – Shell, France

6.1 Integrating Sustainable Development Principles into Shell’s Global Soil and Groundwater Management Program

Presenter: Jonathan Smith (Shell Global Solutions, Netherlands/UK)

Presentation Outline

1. Introduction
2. Sustainable development and Shell
3. What does Shell mean by “sustainable remediation”?
4. How do sustainability considerations fit into Shell’s existing risk-based framework for soil and groundwater?
5. Implementing sustainable remediation in Shell

Presentation Summary

Sustainable remediation comprises soil and groundwater risk-management actions that are protective of human health and the wider environment and which are selected, designed and operated to maximise the net-environmental, social and economic benefits. This paper will describe the implementation of a sustainable remediation programme across Shell’s global soil and groundwater risk-management programme. Shell’s Vision and Mission for sustainable remediation can be seen in Figure 5.

Figure 5 – Shell’s Vision & Mission for Sustainable Remediation
Soil and groundwater assessment and remediation activities commonly adopt risk-based approaches to ensure risks to human health, the environment and other relevant receptors are identified and appropriately managed. Recently there has been growing international interest in extending risk-based approaches to take account of sustainability principles. Sustainable remediation seeks to incorporate environmental, social and economic criteria into remediation decision-making and to deliver better, more sustainable remedial solutions. Ideally the net-benefits of undertaking remediation activities should be greater than the impacts (to the environment, society and economy) of undertaking the works. Shell has operated a risk-based soil and groundwater remediation programme for many years, but in 2012 implemented sustainable remediation globally to supplement the existing risk-based programme.

In line with good international guidance, such as that issued by SURF, SuRF-UK, ITRC and others, a tiered and holistic approach to sustainability appraisal will be adopted. Sustainability objectives will be initially considered in setting business objectives for a remediation project. Once the details of site works start to be considered Tier Zero, Best Management Practices will be applied to all phases of investigation, remediation, monitoring and verification. At the remediation options appraisal stage, a more formal sustainability appraisal will be undertaken to help inform the selection of the best remedial solution at a site.

A variety of sustainable remediation assessment methods are available for assessing the relative merits of different remediation strategies and technologies, such as qualitative screening methods, multi-criteria analysis (MCA), through to fully monetized Cost-Benefit Analysis (CBA). These methods can be applied in a tiered assessment framework, such as that presented by the (SuRF-UK, 2010); a tiered approach is demonstrated in Figure 6. Each sustainability appraisal method has a different level of analysis complexity, data requirement, and associated resource and operator-skill to perform, whilst aiming to aid an assessor’s decision on remediation selection.
Overall it is concluded that sustainable remediation is consistent with Shell’s corporate approach to sustainable development and supplements, not replaces, Shell’s existing risk-based approach. Sustainability appraisals should adopt a tiered approach and be kept simple. Shell believes sustainability can add value across the global portfolio through improving their reputation, encouraging stakeholder acceptance of risk-based solutions and achieving better remediation.

Reference

6.2 Use of SURF-UK Indicators to Evaluate Remediation Alternatives in Northern Ireland
Presenter: James Day, Paul Favara (CH2M, Germany) & David Ellis (Du Pont, USA)

Presentation Outline
1. Introduction
   Overview of step approach
2. Site Overview
3. Overview of SuRF-UK
4. Step 1 – Study goal and scope
5. Step 6 – Assess impacts
6. Step 7 – Sensitivity and uncertainty
7. Step 8 – Interpretation
8. Step 9 – SuRF UK assessment
   *SuRF overview comparison*
   
   *Value comparison*

9. Conclusions

**Presentation Summary**

DuPont is evaluating treatment alternatives for groundwater remediation at their Maydown site in Northern Ireland. This site is contaminated with 1,2-Dichloroethane (EDC) disposed of within warehouse pits. The EDC in the groundwater was migrating to the surface water. Interim measure goals were:

- Reduce contaminant mass flux to River Faughan
- Provide demonstrable improvement of EDC concentrations in river within 12-18 months

SuRF-UK has developed a set of 15 categories of indicators split equally between social, environmental and economic factors. The categories were developed to help practitioners check that their sustainability indicators are suitably holistic, identify gaps in indicator coverage, provide an authoritative listing that stakeholders could benchmark against, provide a hierarchical framework to facilitate assessments, and provide an approach that is “failsafe” in the range of sustainable issues addressed.

DuPont applied these indicators to the Maydown project in conjunction with the CH2M HILL project team using internal Corporate Remediation Group (CRG) technologists. DuPont/CH2M HILL used the SuRF-UK indicator set as a basis for remedial alternative selection. Life-cycle analysis was used in accordance with SuRF’s 9 step process for LCA remediation projects. LCA was used for remedial alternatives, in order to support the interim measure goals. LCA can be used to inform decision makers about the potential environmental impacts of alternatives. LCA results were mapped to applicable SuRF UK indicators to provide DuPont with information about the interface of LCA with the SuRF UK indicator set. Commercial and public domain LCA library used as primary source of life cycle inventory data.

The remedial technologies that were evaluated for implementation at the site are: groundwater pump and treat (P&T), various configurations of groundwater air sparging and monitored natural attenuation. These technologies were evaluated for implementation as a barrier technology to control off site migration of site contaminants.

The impacts of remediation were assessed and normalised with world population as a screen to determine minor vs. major contributors. Separate analysis occurred of higher uncertainty impact categories, such as toxicity, from other impact categories. Identification of categories that are the main contributors to impacts was also undertaken. Areas of uncertainty were identified for both LCA in general and those specific to this project.

The conclusions of the assessment determined the remedial option of air sparging with horizontal wells to be the most sustainable alternative, due to least disruption of riverbank ecology. For this project, one of the most potentially challenging issues to address is the competing attributes of the SuRF UK indicators (i.e. low impact remedies like MNA have a smaller environmental footprint compared to active remedies that have more environmental impacts).
6.3 Optimizing Remediation Sustainability Using a Two-step Stochastic Method

Presenter: Gary Wealthall (Geosyntec Consultants, Canada)

Presentation Outline

1. Introduction
2. Evaluating sustainability overview
   *SuRF 9 steps*
   *Life cycle assessments*
   *SimaPro advantages*
3. Implementing method
   *Case study – coal tar site*
   *Remedies evaluated*
   *Building LCAs*
   *Probability*
   *Rankings*
   *SimaPro – analyze uncertainties*
   *Optimize*
   *Iterative improvements*
4. Conclusions

Presentation Summary

Sustainability is a fundamental condition for the long term success of any activity, company, or society. Recently many corporations, organizations, and governmental agencies have been putting a greater emphasis on evaluating and improving sustainability of projects and products. Using a coal tar contaminated site case study, this presentation illustrates a two step-procedure to i) optimize sustainability and ii) establish a data optimization framework.

The two step procedure to optimize sustainability is simple, but necessary. To utilise this procedure we first generate a list of remedies that are relevant to the site contamination, and then evaluate the sustainability of the individual remedies. This is done using Life Cycle Assessments as part of SuRF’s “9 steps” (shown in Table 2, below). After selecting the most sustainable remedy, a contribution analysis where we identify remedy components that are the greatest contributors to negative sustainability impacts is performed. The less sustainable components are then substituted for more sustainable, but still effective, alternatives.
Monte Carlo analysis is employed to generate easy-to-interpret data that adds an additional level of sophistication in determining which remedies are most sustainable. The use of stochastic methods provides a powerful tool to analyse the sensitivity of individual sustainability calculations to variability that is inherent in remedy implementation, e.g. the possible range of days to complete a project. Using user defined uncertainty data, the Monte Carlo method creates a probability distribution of sustainability outcomes (e.g. tons CO\textsubscript{2} released). The distributions from each remedy are evaluated on a single graphical plot. The resulting curves are described by three broad categories, which indicate complete overlap, partial overlap, or no overlap. Regardless of extent of overlap, the data stochastic distributions are much easier to interpret compared to other methods of analysing sensitivity such as, examining average-case, best-case, and worst-case outcomes.

In the case study (a coal tar site) three remediation technologies were evaluated: (1) an innovative method of combusting the contamination \textit{in-situ} (Self-Sustaining Treatment for Active Remediation, STAR); (2) Low-Temperature Thermal Desorption; LTTD; and (3) Excavation and off-site disposal. Geosyntec’s evaluation procedure for selected remedies is shown in Figure 7, below. Uncertainties were evaluated using SimaPro, a Life Cycle Assessment (LCA) tool that uses the Monte Carlo method and a powerful contribution analysis function. The results of this analysis are shown in Figure 8. Step one concluded that the first option (STAR) was most sustainable. Step two showed that the initial choice of barrier wall (a sheet pile wall) was a major contributor to negative sustainability impacts. The step two comparison of four different barrier wall types (Soil-Bentonite, Cement-Bentonite, Sheet Pile, and Jet Grout) indicated that a soil-bentonite wall would further optimize remediation sustainability.
Figure 7 – Sustainable remedy evaluation procedure

Figure 8 – SimaPro Analysis of Remediation Techniques
6.4 Syndial Approach to Sustainable Remediation – an Italian Case Study

Presenter: Emanuela Gallo, Giorgio Bianchi and Luciano Zaninetta (Syndial, Italy)

Presentation Outline

1. Introduction
   Syndial
   Eni’s commitment
   Motivations

2. Legal standpoint
   Case studies

3. Overview of programme
   Case study

4. Application of SAF

5. Conclusions

Presentation Summary

Syndial is part of the Eni group and has the mission of managing environmental activities required to restore industrial sites. Eni is committed to sustainability and believes being sustainable means creating value for stakeholders and using resources so as to avoid compromising the needs of future generations.

Sustainability is not well recognised in Italian legislation, the few legislative indications that exist towards sustainability are focussed on waste. Public authorities focus on remediation activities that can be considered unsustainable. For example, 50% of risk reduction measures for soils involve excavation and off-site disposal. However, a new culture of sustainability is developing via court decisions of agreements settled with local authorities. Detailed herein are three cases studies in which legal entities helped in sustainable development of clean-up activities.

Case 1 - Priolo, Sicily, is a multi-company site of around 43 km$^2$ including 15km of coast. Since the 1950s, oil refineries, petrochemical and cement plants have been operating in the area. The harbour is also industrially important with high volumes of traffic annually. During the remediation of the site the Ministry of the Environment undertook an investigation to determine contamination of the adjacent sea waters. Main contaminants discovered were mercury and petroleum hydrocarbons. Contaminant sediments were ordered to be dredged.

Around 13 million m$^3$ of sediments were required to be removed. Difficulties involved included the possibility of ships causing sediment re-suspension. This justified the closure of the harbour. Services provided to the local community by the harbour were therefore lost. No environmental, ecological or human-health risk
assessment, nor a cost-benefit analysis had been conducted with regard to the above-mentioned closure. The Court of Justice (10th March 2010) determined the following principles with regards to the case:

- Remediation measures must be chosen in accordance with a sound procedure and must meet substantive beneficial criteria in order to balance land use, services and benefit restrictions.
- Remedial measures that are unsustainable from a technical, environmental and financial point of view must be excluded.

Case 2 - five mining sites in Tuscany. Mining sites have unusual characteristics from both a legal and technical standpoint. They may have specific characteristics that make them of concern from an environmental standpoint e.g. concentration levels of substances above legal limits. Such sites require a balance between remedial activities and environmental impacts of remediation (i.e. closure of mine may involve an environmental impact) No laws exist in Italy to co-ordinate the aforementioned activities.

During the closure and remediation of the mines on the sites, high quantities of highly contaminated groundwater being discharged needed to be managed. Local Authorities requested the construction of a water treatment plant at each mine gallery (a total of 7/8 plants) to reduce contamination to below legal limits. Eni made a deal with the Local Authorities to meet the need to close mines, alongside the requirement to prevent the discharge of contaminated waters to rivers and minimise costs and inefficiencies for the company. A suitable solution was eventually determined: building one unique water treatment facility to provide cleaned water for agricultural use.

Case 3 – ISAF – Gela Phosphogypsum Landfill (Shown in Figure 9). This site has been used as a landfill from 1992 to present. The site is planned to be remediated into a photovoltaic site to allow for renewable energy production providing local economic development with a low carbon footprint. Development of the site would include isolation of the phosphogypsum deposit and in site landfill leachate treatment.
These case studies provided Syndial with the instruments to develop sustainable remediation measures. The Porto Torres site in Sardinia is given as the first relevant example of Green Economy, where clean-up activities represent the first step of the project. The aim was to transform this 1200 ha chemical site using bioplastic technologies. Local products (e.g. biomass) were used as raw materials for a bio refinery to develop a photovoltaic power station. This program started in 2011, using a sustainable restoration programme. A Sustainable Assessment Framework was applied to soil clean-up activities. As part of this, a feasibility study was undertaken (see Figure 10 for remediation techniques assessed) including a technology screening for different remediation scenarios.
7. Session 7: Sustainable remediation using phyto- techniques

Session Chair: Hans Groot – Deltares, The Netherlands

7.1. Engineered Phytoremediation at an Industrial Site Contaminated with Aromatic Hydrocarbons

Presenter: Frank Volkering (Tauw), Edward Gatliff (Applies Natural Sciences, Inc.) and Wim Staal (Dow Benelux bv)

Presentation Outline

1. Site background
   - Conceptual site model
   - Contamination

2. Remediation assessment
   - Technology selection

3. Sustainability
   - Assessment
   - CO₂ footprint

4. Phytoremediation of MAH
5. Phytoremediation pilot setup
6. Pilot results
   - Tree health
     - Effect on hydrology
     - Effect on groundwater
     - Effect on soil
     - Contaminant evaporation

7. Conclusions

Presentation Summary

At a former styrene production facility at a chemical production plant in The Netherlands, the shallow subsurface is contaminated with monoaromatic hydrocarbons (MAH). Although the contamination is not causing unacceptable risks and immediate remediation is not required by the authorities, the owner of the site preferred that the site to be cleaned up for future redevelopment. Based on the aerobic biodegradability of MAH, aerobic bioremediation was considered the best remediation technology. A biosparging pilot at the site showed that the soil was less permeable than anticipated, resulting in a low radius of influence and insufficient oxygen delivery.
In search of an alternative approach, several remediation technologies were assessed in terms of feasibility and sustainability. Given the available time for remediation and the clients’ wish for a sustainable approach, engineered phytoremediation was selected. To determine the site-specific feasibility of phytoremediation, a pilot application is currently being performed at an area of 40 x 60 m. The baseline study showed variable contaminant levels with two zones highly contaminated with benzene, ethylbenzene, and styrene. MAH concentrations in soil ranged from < dl to 11,500 mg/kg, MAH concentrations in the shallow groundwater ranged from 55 to 222,000 µg/l.

In 2010, 33 willow trees of a local variety (Salix alba) were planted in the pilot area. To establish the protection requirements of the trees against the contamination, three different planting configurations have been used (see Figure 21):

- Typically planted trees
- The engineered phytoremediation TreeWell® system, in which trees are planted in a deep, large-diameter optimized planting hole, the wall of which is lined with an impermeable LDPE material
- The modified TreeWell® system, which is similar to a normal TreeWell® system, but without the liner

![Figure 21 - Planting Configurations](image)

After two years of closely monitoring the hydrology and the soil and groundwater quality in the pilot area, the following conclusion can be drawn:

- The trees have a measurable effect on the local hydrology. During the growing season, the groundwater table is slightly drawn down by the trees.
- The trees grow well in moderately contaminated zones (< 1,000 mg/kg MAH), resulting in a significant decrease of the contaminant concentrations in both soil and groundwater
In the zone where the presence of a LNAPL is suspected, the trees are not growing well. Here, little or no influence on the contaminant concentrations is measured – a common observation in the presence of a NAPL source.

Limited contaminant evapotranspiration is observed.

Based on the positive results of the pilot application, the current plan is to extend the phytoremediation to the complete former production facility with modified TreeWell® units. In LNAPL zones, trees will be protected with a shallow liner and combination with a low-intensity LNAPL-recovery system is foreseen.

7.2 Overcoming Barriers to Effective Phyto-management of Contaminated Land - the GREENLAND Project

Presenters: Nele Witters (University of Hasselt); Co-Authors: Paul Bardos, Markus Puschenreiter, Michel Mench, Valerie Bert, Jurate Kumpiene, Petra Kidd and Andrew Cundy

Presentation Summary

Gentle Remediation Options (GRO) are risk management techniques that result in no gross reduction in soil functionality / soil ecosystem services (or a net gain). Hence they have particular usefulness for biologically productive soils, and show considerable potential as more sustainable or “green” remediation or site management tools. GROs encompass a number of technologies which include the use of plant (phyto-), microbial or fungal (myco-) based methods, with or without chemical additives, for reducing contaminant transfer to local receptors by in situ stabilization of contaminants (using biological or chemical processes), or extraction of contaminants. The application of GROs as practical site solutions however is still in its relative infancy, despite a substantial research investment. The barriers to wider adoption, particularly in Europe, arise from:

(a) the fact that many remediation projects are targeted on meeting regulatory demand for critical situations and/or to stimulate the re-use of brownfield land (GRO are frequently perceived as slow and more suited to large area problems); and

(b) market perceptions of uncertainties in achieving effective risk management in the long term.

This paper reports on the on-going EU FP7 KBBE (Knowledge Based Bio-Economy) GREENLAND project (Gentle remediation of trace element contaminated land), initiated in 2011 to overcome these barriers and bring GRO closer to practical application within Europe. The project draws together 17 partner organisations to examine:

1. The practical effectiveness of GRO (focusing on phyto-technologies) in several long-term site trials;
2. Use and valorization of biomass produced during the phytoremediation process;
3. Derivation of methods for soil analysis to better assess the progress and efficiency of phytoremediation;
4. Use of biotechnological tools to increase phytoremediation efficiency;
5. Development of a decision support tool for stakeholders and publication of best-practice guidance for practical site application.

GRO may provide important, and more sustainable, alternatives to conventional “hard” remediation methods due to their relatively low capital costs and the inherently aesthetic nature of planted or “green” sites. In addition, “greening” of contaminated land may have benefits far beyond risk management in terms of resource generation (biomass), educational and amenity value, CO₂ sequestration, resource deployment (compost outlets) and ecosystem services.
8. Concluding Remarks

1. **The basic knowledge needed for effective implementation of sustainable remediation is already available, i.e. definitions, indicator sets, flowcharts, best management practices and checklists.**
   The workshop has shown that several practical tools are available for use, (e.g. the NICOLE Roadmap and the SuRF-UK Briefcase, Tier 1 of the Best Management Practices) as well as for more experienced users (e.g. Tier 2 and 3 of the SuRF-UK BMPs). A wide range of tools are available, from very complex assessment systems requiring the answering of 200 comprehensive questions (CEEQUAL) or alignment with a lot of stakeholders (URS Sustainable Analysis/EcoNomics™) to very simple ones. Some tools have been, or will soon be, translated into software. A tiered approach to sustainability assessment will likely be both most efficient in use of resources and more complete. At an entry level simple approaches will either yield an adequate basis for decision making, or highlight where more intensive work needs to be carried out. Hence, using simple tools first allows a project to quickly assess which options are realistic, whether a decision is easily possible and if not what needs to be done next. Based on the SuRF-UK Framework the Shell expectation is for 90% of project decisions to progress no further than SuRF-UK Tier 1 (qualitative methods), around 9% Tier 2 (semi-quantitative methods) and less than 1% reaching Tier 3 (quantitative methods).

2. **The development of further knowledge should be a balanced process, in which data from international scientific projects should be combined with empirical evidence from projects in which sustainable remediation is implemented.**
   There is a certain drive here, as e.g. in Italy recent court decisions show that remediation solutions should include sustainable considerations by including social and economic factors in the decision making process. Several international research projects like HOMBRE, TIMBRE and Greenland are engaged with sustainable remediation (and regeneration).

3. **Authorities and other concerned parties find it a challenge to link sustainable remediation to the spatial planning process.**
   It is clear that sustainable remediation considerations are useful to apply within other decision making processes. It was suggested that NICOLE could help here. One way of doing this could be the development of a guide to available tools.

4. **Sustainable remediation drives innovation in contaminated land management.**
   Sustainable remediation already supplements existing risk based remediation decision making approaches. It does not substitute for them.

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**Portuguese policy on soil contamination**

Presented by Paula Meireles, Ministry for Agriculture, Sea, Environment and Spatial Planning (MAMAOT)/Office of Planning and Policy (GGP).

In her keynote address Ms. Meireles expressed the intention of the Portuguese government to publish a policy on soil contamination by the end of 2013. For the development of this policy legislation from five European countries, two US states (Texas and Washington) and the Canadian province of Ontario were reviewed. In the draft version presented, the Portuguese screening values are based on the Ontario standards, because those are the most conservative. Until Portugal has developed its own standards one can apply either the Ontario screening values, or, provided this is well motivated, other values.
Guidances and regulations continue to be developed for Hg. In addition, it is noted that there is an international Conference on Mercury as a global Pollutant scheduled for 29 July - 2 August, 2013 in Scotland (www.mercury2013.com) and that the UNEP has targeted 2013 as a year in which to reach legally binding agreements internationally to address the mercury issue.

Data Acquisition for a Good Conceptual Site Model, Carcassonne, France 10-11 May 2006

Making Management of Contaminated Land an Obsolete Business – Challenges for the future (NICOLE 1996-2006 Ten Year Anniversary Workshop), Leuven, Belgium 5-6 October 2006

Redevelopment of sites – the industrial perspective. Akersloot, the Netherlands 14-15 June 2007


Sustainable Remediation, London, UK 3 March 2008

Environmental Decision Support Systems, Madrid, Spain 9-10 October 2008

Basics and Principles of Environmental Law, Brussels, Belgium 31 March 2009

Sustainable Remediation - A Solution to an Unsustainable Past? Leuven, Belgium 3-5 June 2009

From Site Closure to Disengagement, Douai, France 18-20 November 2009

Contaminated land management: opportunities, challenges and financial consequences of evolving legislation in Europe, Triest, Italy 5-7 July 2010

Emerging contaminants and solutions for large quantities of oil contaminated soil (Technical meeting), Brussels, Belgium 4 November 2010

Operating Windows for site characterisation, Copenhagen, Denmark 25-27 May 2011

Rotterdam Revisited; a renewed look at soil and groundwater management, Rotterdam, the Netherlands 16-18 November 2011

Water in Contaminated Land Management, the challenge of preservation of our water resource, Baden-Baden, Germany and Lauterbourg, France 13-15 June, 2012

For a complete overview of all networks meetings that have been held from the start of NICOLE up to now see www.nicole.org.
Implementation of Sustainability in Management of Contaminated Land – in particular using emerging 'green' technologies

NICOLE Network meeting & workshop
Lisbon, 12-14 June 2013

Introduction
NICOLE has described a sustainable remediation project as one that represents the best solution when considering environmental, social as well as economic factors – as agreed by the stakeholders. This debate has been the subject of several meetings and special sessions, e.g. during the NICOLE workshop held in Leuven, Belgium, 4-5 June 2009, 'Sustainable remediation – A solution to an unsustainable past?'. NICOLE would like to facilitate a shift in this discussion towards practical implementation. Moreover, NICOLE wants to promote a common understanding for Sustainability in Management of Contaminated Land, which includes popular terms like 'Green Remediation' and 'Green Technologies'.

The NICOLE Spring Workshop 2013 aims at showing examples and experiences on how contaminated sites can be remediated eco-efficiently, leaving a smaller environmental footprint, and how their reuse can contribute to a more sustainable development. This encompasses both approaches to deployment and decision-making, and technologies. In addition, intrinsically eco-friendly, eco-efficient techniques have been developed, such as phytotechnologies, use of biochars and other recyclates, mulch barriers, helophyte filters, etc. However, examples of their practical deployment are limited. NICOLE seeks to facilitate adoption of more sustainable strategies and techniques, and to understand whether there are barriers to this, and if so, how they could be overcome.
### Wednesday 12 June 2013

**MEETING OF NICOLE WORKING GROUPS AND SUBGROUPS**  
Venue: CS Vintage Lisbon – Rua Rodrigo da Fonseca 2, 1250-191 Lisbon, Portugal

<table>
<thead>
<tr>
<th>Time</th>
<th>Activity</th>
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</table>
| 09.00-10.30 | Parallel meetings of NICOLE Working Groups:  
- Sustainable Remediation  
- Mercury             |
| 10.30-11.00 | **COFFEE BREAK**                                  |
| 11.00-12.30 | Meeting Regulatory Working Group                  |
| 12.30-13.30 | **LUNCH**                                         |
| 13.30-17.30 | ISG Meeting                                      |
| 14.30-17.30 | SPG Meeting                                      |
| 17.30-18.30 | **Welcome drinks**                               |
| 18.30-19.00 | **General Assembly meeting**                      |
| 19.00-21.30 | ISG Information Exchange meeting                  |
**Thursday 13 June 2013**

**CONFERENCE DAY 1**

**Venue:** School of Economics and Management Lisbon (ISEG) - Rua do Queihas 6, 1200-781 Lisbon

<table>
<thead>
<tr>
<th>Time</th>
<th>Session</th>
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<tbody>
<tr>
<td>08.30-09.00</td>
<td>Registration</td>
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<tr>
<td>09.00-09.15</td>
<td><strong>OPENING SESSION</strong>&lt;br&gt;Chair: Lucia Buvé (Umicore – Belgium)</td>
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<tr>
<td>09.15-09.35</td>
<td><strong>Opening and welcome</strong>&lt;br&gt;- by Lucia Buvé, session chair (Umicore – Belgium)</td>
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<tr>
<td>09.15-09.35</td>
<td><strong>Keynote speech</strong>&lt;br&gt;- by Paula Meireles (Ministry for Agriculture, Sea, Environment and Spatial Planning (MAMAOT) / Office of Planning and Policy (GGP) – Portugal)</td>
</tr>
<tr>
<td>09.35-09.50</td>
<td><strong>Update on NICOLE</strong>&lt;br&gt;- Steering Group – by Lucia Buvé, Steering Group chair&lt;br&gt;- Working Groups – by Working Group Leaders</td>
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<tr>
<td>10.50-10.30</td>
<td><strong>Framing the workshop topic</strong>&lt;br&gt;- by Arthur de Groof (Grontmij – Netherlands &amp; NICOLE OC Chair)</td>
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<tr>
<td>10.30-11.00</td>
<td><strong>COFFEE BREAK</strong> in poster area</td>
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**SESSION 2:**

**Development of sustainability frameworks - 1**

**Chair:** Peter Wouter (ENVIRON – Spain)

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<th>Time</th>
<th>Session</th>
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<tbody>
<tr>
<td>11.00-11.30</td>
<td><strong>The Common Forum-NICOLE joint position statement on sustainable remediation</strong>&lt;br&gt;- by Dominique Darmendrail (BRGM – France &amp; Common Forum Secretary) and Lucy Wiltshire (Honeywell – United Kingdom &amp; NICOLE member)</td>
</tr>
<tr>
<td>11.30-12.00</td>
<td><strong>Development of practical guidance to promote sustainability considerations in land contamination management in the UK</strong>&lt;br&gt;- by Brian Bone (SuRF-UK Steering Group – United Kingdom)</td>
</tr>
<tr>
<td>12.00-12.30</td>
<td><strong>Flanders implements green and sustainable remediation by a threefold approach</strong>&lt;br&gt;- by Griet van Gestel (OVAM – Flanders, Belgium)</td>
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<td>Time</td>
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<tr>
<td>12.30-13.00</td>
<td>Questions and discussion</td>
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<tr>
<td>13.00-14.00</td>
<td>LUNCH</td>
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</table>
Thursday 13 June 2013 (continued)
CONFERENCE DAY 1
Venue: School of Economics and Management Lisbon (ISEG) - Rua do Quelhas 6, 1200-781 Lisbon

**SESSION 3:**
Implementing sustainability approaches in remediation projects - 1
Chair: Oliver Phipps (ERM – United Kingdom)

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<thead>
<tr>
<th>Time</th>
<th>Presentation</th>
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| 14.00-14.30 | Field development of 'in situ reactive zone' (IRZ) for the sustainable treatment of Chromite ore processing residues (Copr) Heap  
- by Thomas Wohlhuter (Arcadis – France) |
| 14.30-15.00 | Life cycle assessment of soils and groundwater remediation with zero valent iron nanoparticles: Results from a pilot study in Barreiro, Portugal  
- by Helena Gomes and Celeste Jorge (CENSE (Center for Environmental and Sustainability Research) – Portugal) |
| 15.00-15.30 | Mulch biowalls as low cost sustainable remediation for contaminated soils and groundwater  
- by Kevin Morris (ERM – United States of America) |
| 15.30-16.00 | Questions and discussion |
| 16.00-16.30 | **COFFEE BREAK** in poster area |

**SESSION 4:**
Sustainable remediation using renewable energy
Chair: Philippe Menoud (Dupont – Switzerland)

<table>
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<tr>
<th>Time</th>
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| 16.30-17.00 | Green soil remediation projects at the Bilthoven and Amersfoort sites  
- by Johan van Leeuwen (Stichting Bodemsanering NS – Netherlands) |
| 17.00-17.30 | Parys Mountain metal mine, Anglesey, Wales: Sustainability in mine water remediation  
- by Rick Parkman (URS Infrastructure & Environment – United Kingdom) |
| 17.30-18.00 | Questions and discussion |
| 19.30-22.00 | NICOLE CONFERENCE DINNER  
**Venue:** Sr. Vinho Restaurant – Rua do Meio a Lapa 18, 1200-723 Lisbon |
**Friday 14 June 2013**  
**CONFERENCE DAY 2**  
**Venue:** School of Economics and Management Lisbon (ISEG) - Rua do Quelhas 6, 1200-781 Lisbon

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<thead>
<tr>
<th>Time</th>
<th>Session</th>
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| 09.00-09.30 | Optimizing the remediation solution for a complex solvent plume, following the NICOLE road map  
- by Tracy Braithwaite (AWE – United Kingdom) and Matthew Pearce (WorleyParsons – United Kingdom) |
| 09.30-10.00 | Sustainability assessment of the redevelopment of Hexion with CEEQUAL  
- by Petra Brinkhoff (NCC Construction – Sweden) |
| 10.00-10.30 | Sustainability assessment of remedial options for a former oil terminal site  
- by Richard Bewley and Emily Ghedia (URS Infrastructure & Environment – United Kingdom) |
| 10.30-11.00 | Questions and discussion                                                                     |
| 11.00-11.30 | COFFEE BREAK in poster area                                                                 |

**SESSION 6:**  
**Development of sustainability frameworks - 2**  
**Chair:** Elise Noël (Shell – France)

<table>
<thead>
<tr>
<th>Time</th>
<th>Session</th>
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</table>
| 11.30-12.00 | Integrating sustainable development principles into Shell’s global soil and groundwater management program  
- by Jonathan Smith (Shell Global Solutions – Netherlands/United Kingdom) |
| 12.00-12.30 | Use of SURF-UK indicators to evaluate remediation alternatives in Northern Ireland  
- by James Day and David Ellis (CH2M – Germany / DuPont – United States of America) |
<p>| 12.30-13.30 | LUNCH                                                                                     |</p>
<table>
<thead>
<tr>
<th>Time</th>
<th>Presentation</th>
<th>Speaker/Institution</th>
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<tbody>
<tr>
<td>13.30-14.00</td>
<td><strong>Optimizing remediation sustainability using a two-step stochastic method</strong></td>
<td>by Gary Wealthall (Geosyntec Consultants – Canada)</td>
</tr>
<tr>
<td>14.00-14.30</td>
<td><strong>Syndial approach to sustainable remediation - an Italian case study</strong></td>
<td>by Emanuela Gallo, Giorgio Bianchi and Luciano Zaninetta (Syndial – Italy)</td>
</tr>
<tr>
<td>14.30-15.00</td>
<td><strong>Questions and discussion</strong></td>
<td></td>
</tr>
</tbody>
</table>
Friday 14 June 2013 (continued)
CONFERENCE DAY 2
Venue: School of Economics and Management Lisbon (ISEG) - Rua do Quelhas 6, 1200-781 Lisbon

<table>
<thead>
<tr>
<th>Time</th>
<th>Session</th>
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</table>
| 15.00-15.30| **Engineered phytoremediation at an industrial site contaminated with aromatic hydrocarbons**  
- by Frank Volkering (Tauw – Netherlands / Dow – Netherlands) |
| 15.30-16.00| **Overcoming barriers to effective phyto-management of contaminated land – the GREENLAND project**  
- by Nele Witters (University of Hasselt – Belgium) |
| 16.00-16.15| **Questions, discussion and wrap up**                                    |
| 16.15      | **CLOSING**                                                                
- by Prof. João Luis Correia Duque (President ISEG) |
NICOLE Organization Committee

Arthur de Groof (Grontmij – Netherlands)(chair)
Hans-Peter Koschitzky (VEGAS / University of Stuttgart – Germany)(vice-chair)
Paul Bardos (R3 Environmental – United Kingdom)
Ettore Ferrari (ENI – Italy)
Hans Groot (Deltares – Netherlands)
Philippe Menoud (DuPont – Switzerland)
Allessandro Nardella (ENI – Italy)
Elise Noël (Shell – France)
Matthew Pearce (WorleyParsons – United Kingdom)
Alan Thomas (ERM – United Kingdom)
Peter Wouters (ENVIRON – Spain)

NICOLE Secretariat

For further information on NICOLE membership, workshop program, registration & fees, or any other practical issue with regards to the conference, please contact:
Nan Su (Dutch Sino Business Promotions)
P.O. Box 28249 – 3003 KE Rotterdam, The Netherlands
Phone: +31 (0)6 41374680
E-mail: nan.su@nicole.org

Venues

NICOLE Network meeting | CS Vintage Lisbon
Rua Rodrigo da Fonseca 2 – 1250-191 Lisbon, Portugal

Conference & workshops | School of Economics and Management Lisbon (ISEG)
Rua do Quelhas 6 – 1200-781 Lisbon, Portugal

Conference dinner | Sr. Vinho Restaurant
Rua do Meio a Lapa 18 – 1200-723 Lisbon, Portugal

Registration

Please complete the conference registration form, available online through NICOLE.org and/or the NICOLE secretariat. Deadline for registration: 5 June 2013.

Fees

Participation in the NICOLE Spring 2013 Workshop is free of charge for NICOLE members, Common Forum members, and conference speakers. Information on admission fees for other participants can be obtained through the NICOLE secretariat.
Participation in the Conference Dinner on 13 June 2013 at the Sr. Vinho Restaurant will be settled individually at € 50 per cover.