Danish Ministry of the Environment
Environmental Protection Agency

Environmental Economic Assessment Tools
Remediation Technologies

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NIRAS

Environmental Project No. 1369 2011

Indhold

Sammenfatning: Miljøøkonomiske værktøjer

Denne rapport belyser økonomiske metoder, det er muligt at benytte til at understøtte beslutninger om oprensning af jord- og grundvandsforurening. Det kan ske som supplement til de teknisk set mest fordelagtige løsninger, hvor de økonomiske betragtninger kan hjælpe til at prioritere inden for et grundvandsopland eller et større geografisk område. Rapporten giver endvidere et overblik over de netværk, der er etableret i dag for at danne gode rammer og udveksle erfaringer for, hvilke beslutninger der er mest hensigtsmæssige.

Baggrund og formål

REMTEC-projektet er et stort forskningsprojekt inden for afhjælpning af jord- og grundvandsforurening med fokus på udvikling af nye omkostningseffektive oprensningsteknologier. Projektet kører over 4 år fra 2008 til 2011 og er et samarbejde mellem DTU, GEUS, Århus Universitet (DMU) samt fire konsulentfirmaer (NIRAS, COWI, Orbicon, Geosyntec Consultants). Projektet består af 6 delelementer (work packages: WP). WP 6 omhandler den miljøøkonomiske vurdering og denne del varetages af NIRAS og DMU.

Formålet med denne rapport er at give et overblik over de miljøøkonomiske vurderinger, der kan anvendes til at forbedre beslutningsgrundlaget for, hvor det er mest hensigtsmæssigt at afhjælpe en jord- og grundvandsforurening. Rapporten danner dermed en ramme for at udvikle et operationelt miljøøkonomisk værktøj, der kan bruges til at prioritere mellem afværgeprojekter inden for et grundvandsopland eller inden for et større geografisk område.

Undersøgelsen

Denne rapport er udarbejdet af NIRAS ved Connie Nielsen, Klaus Weber og Camilla Damgaard i regi af WP6 under REMTEC-projektet. Vi takker dette projekt for de gode rammer til at diskutere foreløbige udkast til rapporten, hvilket er sket i WP6-arbejdsgruppen, hvor professor Poul Løgstrup Bjerg (DTU), adjunkt Gitte Lemming (DTU) og seniorforsker Berit Hasler (DMU) har kommenteret foreløbige udkast til rapporten.

Hovedkonklusioner

Der er initiativer i gang for at opbygge netværk, der kan fremme bæredygtige løsninger til udbedringer af jord- og vandforurening. Blandt teknikere er der endvidere et udbredt ønske om at supplere deres søgen efter den teknisk set bedste løsning med økonomiske prioriteringsværktøjer. Denne rapport har vist, at der allerede findes forslag til løsninger, men at der mulighed for at forbedre dette grundlag. Vi vil bygge på dette grundlag i det videre arbejde, hvor vi vil opstille et økonomisk prioriteringsværktøj.

Projektresultater

Kapitel 2 i rapporten beskriver forskellige økonomiske metoder, som det er muligt at benytte for at kunne understøtte beslutninger om miljømæssige forbedringer. Først er der en oversigt over mulige måder at værdisætte eksternaliteter, der ikke er afspejlet i de markedsbestemte priser. For at beslutningstagere kan prioritere mellem forskellige indsatser vil det ofte være nødvendigt at kende den samlede økonomiske værdi. Hvis der er tale om et miljøtiltag, er det vigtigt at kende dose-response forholdet for at kunne værdisætte (dvs. forholdet mellem omfanget af en miljøforbedring og den målte virkning for fx helbred, dyreliv og landskab). Hvis de tekniske forhold er givet, repræsenterer en markedspris på det frie marked købernes maksimale villighed til at betale og sælgernes minimum villighed til at acceptere den pågældende pris. For at skønne den ikke-markedssatte pris af en miljømæssig ændring, er det muligt at benytte forskellige metoder, der overordnet set kan opdeles i ”stated preferences” eller ”revealed preferences”. Stated Preferences belyser, hvad individer vil betale for en indsats på et hypotetisk marked ved at stille spørgsmål i et spørgeskema, og revealed preferences forsøger at afdække individernes betalingsvillighed på faktiske markeder. Når fordele og ulemper ved en indsats er prissat, er det op til valg af økonomisk metode at få rangordnet de forskellige indsatser, det er muligt at vælge. Der kan her være tale om Cost Benefit Analysis, Cost Effectiveness analysis og/eller en Multi Criteria Analysis.

Kapitel 3 er en litteraturoversigt, der beskriver, hvordan de økonomiske metoder er benyttet i den eksisterende litteratur inden for jord- og grundvandsforurening.

I Appendiks er der en oversigt over de eksisterende netværk, der har til formål at tilvejebringe hjælp i forbindelse med jord- og grundvandsforurening.

Andre kilder

Appendix til rapporten giver en oversigt over netværk, der fremmer gode løsninger til problemer, hvor der er jord- og vandforurening. To vigtige kilder i den forbindelse er:

The Sustainable Remediation Forum (Surf US) fremmer bæredygtige afværgeteknologier, idet de afbalancerer, at det kan lade sig gøre økonomisk, bevarelse af naturværdier, forbedret biodiversitet og nærmiljø.

Surf US www.sustainableremediation.org/

United Kingdom’s Sustainable Remediation Forum (Surf UK). For det første er formålet i Surf UK at udvikle en ramme for at kunne lave afbalancerede beslutninger vedrørende afværgeteknologi for at integrere beslutninger for forurenet jord i et mere overordnet bæredygtigt perspektiv. For det andet har netværket lavet tjeklister med indikatorer, der giver klare og effektive vurderinger for bæredygtighed. Den generiske tilgang vil blive testet med case studier for at kunne udsende anbefalinger og for at kunne forbedre vejledningen i Surf UK regi.

Surf UK www.claire.co.uk og www.nicole.org

1 Introduction

The REMTEC project addresses a growing societal need for effective technologies for removing or immobilizing toxic contaminants that threaten water resources and soil quality. The project is a strategic research program for the environment financed by the Danish Ministry of Science, Technology and Innovation (Ministeriet for Videnskab, Teknologi og Udvikling). Moreover, the Danish Environmental Protection Agency (Miljøstyrelsen) has supported the project, which has made it possible for us to prepare this literature review on economic evaluations.

This paper provides an overview (i.e. a literature review) exemplifying tools and methods for environmental economic assessment of remediation at contaminated sites within a groundwater catchment area or a region. The work is part of the sixth work package (WP6) in the REMTEC project. The literature review can serve as a starting point for the economic evaluation tool to be developed within the REMTEC project. This tool will aim to assess remedial interventions in a groundwater catchment with respect to their effectiveness to reduce environmental and human exposure, their cost-effectiveness and to their overall environmental balance. Citing the project description: "The economic assessment will overarch technology development to ensure sustainable solutions and bring the need for prioritization into play." Given scarce resources for remediation, the first stage of a decision is to prioritise among sites that need remediation. At the second stage, if remediation has been decided upon for a certain site, the right technology has to be chosen. The economic-environmental assessment tool to be developed will be useful for supporting decisions at both stages.

A remediation technology is a technology that reduces the risk at the source of pollution. It may either remove/reduce the pollution or immobilise the contaminants to avoid spreading to groundwater or surface water. An integrated decision support tool for selection of remediation technologies for contaminated soil and groundwater consists of technical, environmental and economic evaluations.

Based on technical considerations, applicable technologies for the specific site are selected and their remediation efficiency and cleanup time estimated. As remediation technologies may either seek to remove or immobilise the pollution as described above, contaminant flux reduction is a preferred performance metric to contaminant mass reduction.

From an economic viewpoint the objective is to maximise the benefits and minimise the costs for each remediation alternative in question. A general path of the remediation alternatives links the contaminated site, the soil remediation operations, the consequences of remediation and the fundamental objectives of the remediation. It is straightforward to state the costs of each remediation alternative whereas the benefits can be more difficult to quantify. The benefits may be to avoid the following: adverse effects on health, adverse effects on real estate prices, closing drinking water wells, adverse ecological effects and stagnation of economic potential. Environmental economics is a tool to weigh benefits and costs which is further described in Chapter 2.

One of the "costs" associated with remediation of a contaminated site is the environmental impacts arising from the remediation activities carried out at the site as well as impacts related to up- and downstream activities. In order to quantify these "secondary impacts" of remediation a life cycle assessment (LCA) can be conducted. The term "life cycle" refers to the notion that the environmental burden during the process of remediation has to be assessed including manufacture, distribution, transportation, use of material and disposal of material. LCA can be used to evaluate the inherent trade-off between the reduction of a local environmental problem on a site and the negative environmental impacts from the remediation technology (Lemming et al., 2010a).

Besides the consideration of environmental and economic factors, a sustainable remediation requires a set of social factors such as impacts on human health and safety; ethical and equity considerations; impacts on neighbourhoods or regions; community involvement and satisfaction; compliance with policy objectives and strategies; and uncertainty and evidence (Smith et al., 2009). In other words environmental economics and LCA play the role as being decision support tools for sustainable solutions.

The local and global institutional settings also create a framework for the possible decisions of which sites to remediate and which technologies to choose. At the EU level, the applied method has to comply with the requirements of the EU Water Framework Directive. EU acknowledges the economic cost benefit analysis method phrased as "the potential benefits and costs of action or lack of action" in the following citation:

"Pursuant to Article 174 of the Treaty, in preparing its policy on the environment, the Community is to take account of available scientific and technical data, environmental conditions in the various regions of the Community, and the economic and social development of the Community as a whole and the balanced development of its regions as well as the potential benefits and costs of action or lack of action."

According to the Danish Environmental Protection Act, Denmark has a policy to remediate all the contaminated sites where there is a risk that pollution will spread to groundwater that can be used for drinking water supply. The general principle is that the polluter has got to pay either on a voluntary basis or on command. If it is not possible to make any people in the private sector responsible, the public sector has the responsibility. In this case the public sector has to prioritise among projects where remediation is required.

This literature review will find existing studies that include environmental-economic assessment tools. We have defined a broad definition of searching in the literature to include as many ideas for a good combination of the technical, environmental, societal and economic aspects as possible. Besides the literature review, this paper also presents an overview of the current networks where the focus is to remediate contaminated soil and groundwater (see Appendix). The networks both consist of researchers, consultants and regulators. These networks create proposals to change the regulation of the area, which can be seen in for example a paper where they discuss how the decision support tools SURF UK and SURF US can be applied in the Netherlands and in Denmark (Groof and Kirkebjerg, 2009).

2 Environmental Economics

2.1 Economic Assessments

The value of groundwater reflected in the market prices may not represent the total value of groundwater to society as a contributor to recreational use of surface water, to the sustainability of ecosystems, and to natural beauty. It is very likely that the market price of groundwater only reflects its value as an input to production. Economists refer to a situation like this as a ***market failure***. All the benefits or services that are not reflected in the market price are termed ***externalities***. It is often difficult to estimate the benefit of environmental goods that are typically not traded at a market and therefore it is not possible to deduct a price that can enter an analysis. This is the case if one wants to protect an aquifer or if one wants to reconstruct amenities in a polluted region.

In many situations it is worth knowing ***the total economic value*** (TEV) of a resource to society, especially if decision makers need to prioritize.
This section briefly lists different economic valuation techniques that are generally applied within economics. For a more thorough description of the economic valuation techniques, we refer to Hardistry et al. (2005) and Hanley et al. (2007). Before any of the evaluation techniques can be applied, it is necessary that technical experts have assessed the environmental resource which also includes a definition of the changes in its quality and quantity. ***Dose-response relationships*** establish links between dose (i.e. the change of concern as for example pollution) and the response or the impacts of this change on human health, flora and fauna, and landscapes. Given these technical contexts, the equilibrium price at the free market represents the buyers' maximum Willingness To Pay (WTP) and the sellers' minimum Willingness To Accept (WTA). Figure 1 illustrates the terms WTP and WTA.

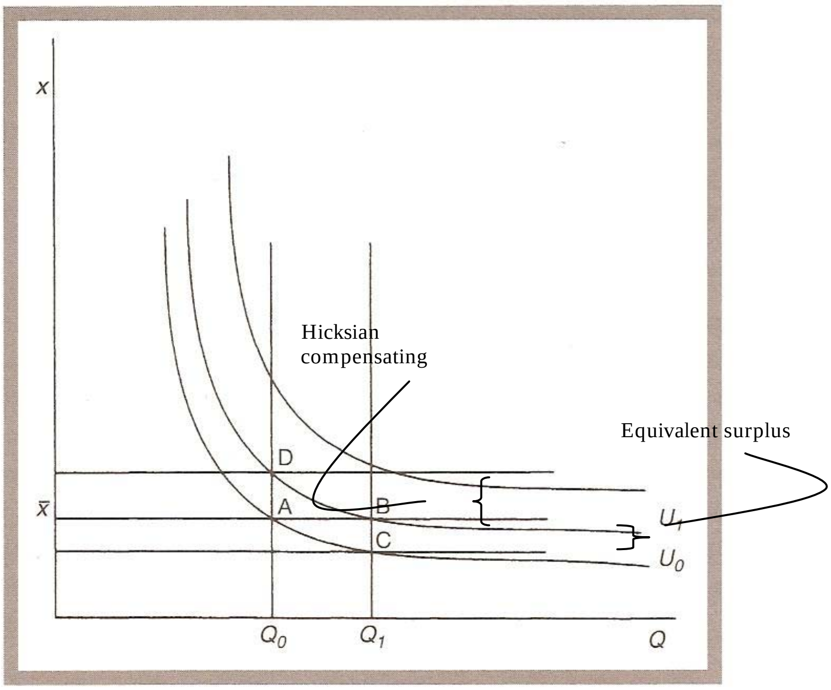

Figure 1: WTP and WTA where *X* is a normal good and *Q* is an environmental good.

Source: Hanley et al. (2007): Environmental Economics in Theory and Practice. Second Edition. Palgrave added explanatios.

In Figure 1, Point A represents the utility level, $\boldsymbol{U_0}$, given the fixed level of the environmental good, $\boldsymbol{Q_0}$, and the market good, $\overline{X}$. An increase in the environmental good from $\boldsymbol{Q_0}$ to $\boldsymbol{Q_1}$, keeping $\overline{X}$ fixed, will increase the utility level from $\boldsymbol{U_0}$ to point B at the utility level $\boldsymbol{U_1}$.

First, asking the question of what an individual is willing to pay for the change from $\boldsymbol{Q_0}$ to $\boldsymbol{Q_1}$ illustrates the notion of WTP. In reply to this question the individual would give up the change in the market good from point B to point C at the original utility level $\boldsymbol{U_0}$. The maximum measured in terms of the market good that the individual is WTP for the change in the environmental good is an equivalent surplus measure.

Second, asking the question of the minimum compensation the individual is willing to accept to forego the increase in the environmental good, illustrates the notion of WTA. The minimum an individual would accept in terms of the market good is to achieve the new utility level $\boldsymbol{U_1}$ (i.e. the difference between points A and D), which is a Hicksian compensating surplus measure of value.

To estimate the non-market, economic value of changes in environmental quality, the valuation methods are usually divided into stated and revealed preference methods. There are two groups of ***stated preference techniques***: Contingent Valuation Method (CVM) and Choice Modelling (CM) where CM has become more and more popular during the last decade (McFadden et al., 2005). Although there are differences between the two methods, they both regress WTP or WTA against factors that are thought to influence this response and they can estimate both use and non-use values. Both the CVM and the CM has to set up a hypothetical market to elicit individuals' WTP/WTA for a specific outcome by way of structured questionnaires. This survey has to be administered by interviewing respondents and to try to achieve a high response rate. ***Revealed preference methods*** use individuals' actual behaviour at real markets in stead of their conjectured behaviour in hypothetical markets. There are two groups of revealed preference techniques: The Travel Cost Method and Hedonic property pricing that can only measure use values, which has a tendency to underestimate the total economic value.

Several studies have tried to reveal the direct costs and the benefits of remediation projects. An example is a study to reveal the 'Willingness to Pay' (WTP) to secure clean water either by purification of the water or by preventing pollution of the aquifer (Hasler et al., 2005; Hasler et al 2007). As a part of the workload in WP6, NERI will investigate the stated WTP for the price of a house related to some kind of pollution or not.

As valuation studies can be quite expensive, it can sometimes be necessary to transfer benefits from other studies. One has though to be careful as it is rare that the estimated prices can be transferred directly from one study to another study.

2.2 Economic Analysis

The ideal situation will be if the operational environmental-economic assessment tool can rank both costs and benefits for multiple remediation projects, which is the case for cost benefit analyses. An overview of both costs and benefits makes it possible to calculate the net present values of the individual remediation projects to see if they are profitable. It will also help to decide which projects are most optimal from an economic perspective of the society.

As it is often too complicated to evaluate the benefits and consequently to be able to prepare a complete cost benefit analysis, a cost effective analysis can be prepared. A cost effective analysis can either investigate the costs of different alternatives to reach a certain environmental goal or investigate different environmental initiatives that can be achieved with a certain amount of money.

The two subsections in the following describe the cost benefit analysis and the cost effectiveness analysis in more detail.

2.2.1 Cost Benefit Analysis

The overall aim of a cost benefit analysis (CBA) is to evaluate whether an investment in question is profitable for the society. This happens if the investment will imply an increment in the welfare as an aggregate sum of the individual welfares. In the CBA a remediation project will be evaluated in terms of the negative consequences on one side and the positive consequences on the other side. Both the negative and the positive consequences will be quantified in monetary units. The negative consequences of a remediation project include expenses for materials, energy resources and the installation. In addition operation costs have to be included. Furthermore, the impacts of the remediation on the environment and the risk reduction for human beings have to be considered. The advantages may be gains in terms of improvements of the environment or the health situation in the population.

Advantages may also be to protect an aquifer and an increased value of land or property.

For both positive and negative consequences (i.e. benefits and costs), a valuation is either based on a marketed or a non-marketed good. The net present value of cleaning a contaminated site of soil or groundwater is defined as the discounted value of the benefits subtracted by the discounted value of the costs:

$$NPV = \frac{(B(t) - C(t))}{(1+r)^t}$$

It is straightforward to compare the positive and negative consequences in a CBA as all the items are quantified in monetary units. It is though necessary to accept the presumption that it is possible to make realistic, economic valuations of all the possible impacts of a certain remediation technology. The greatest challenge is to evaluate the non-marketed goods such as for example impacts on health and the environment. It is possible to apply the valuation methods to acquire estimates of the non-marketed values as described in Section 2.1. Another possibility is to transfer results from other valuation studies, which is then referred to as a benefit transfer.

Assuming that it is possible to make good evaluations of positive and negative consequences for different alternatives, it is possible to compare different alternatives based on the net present values.

2.2.2 Cost Effectiveness Analysis

Typically, the purpose of a cost effectiveness analysis (CEA) finds the solution that meets a well-defined environmental quality criterion given the lowest costs. As a starting point, the cost effectiveness analysis aims at improving a very specific environmental effect. This can happen by not exceeding a certain threshold value in mg/kg for soil, µg/l for water or to reduce the flux (massflow per year). In cost effectiveness analyses, there is no evaluation of the improved environmental benefits in money units. The improved environmental benefit will only be expressed in physical units.

For each alternative of the remediation projects, the costs, which can be capitalised in DKK, in relation to the environmental effect in physical units is calculated (i.e. the C/E-ratio). This type of analysis typically evaluates the marketed goods only. The costs are converted to a present value by the help of a discount factor as in the CBA. Actually, the cost-effectiveness analysis is a partial CBA.

Based on the C/E ratio it is possible to rank the different alternatives of remediation in relation to the environmental benefit. In other words it is straightforward to find the cheapest alternative to obtain a certain environmental effect.

Of course it is a weakness that the cost effectiveness analysis does not take other environmental effects into consideration. It is neither possible to evaluate several environmental improvements at the same time nor to evaluate environmental side effects of the remediation itself. However, it is possible to calculate the C/E ratio for different environmental units or for side effects. As the amount of C/E ratios is increasing, the ranking of the projects will become more and more complicated.

Some analyses have started applying an extended CEA to incorporate more than just one benefit. This is the case in a study (Aalborg Municipality, Denmark) where they both consider improved standards of potable water, outdoor recreation and biodiversity benefits in the CEA by converting farm land into uncultivated land.

2.3 Risk and uncertainty

For all the methodologies of evaluating marginal costs and benefits it is necessary to consider the aspect of uncertainty. The economic analysis has to develop operational methods to handle uncertainty by transforming the uncertainty into risk estimates. Before the economic analysis can take place, technical professionals have pointed out areas that need remediation within a groundwater catchment area or a region. This is done in a risk assessment, where current and expected future contaminant levels in soil, air, surface water and groundwater are compared with quality criteria for these compartments or site-specific cleanup targets. This risk assessment describes the “no action” approach, i.e. the risk when no remediation is carried out and precedes the risk assessment related to remedial action. The risk related to the no action scenario seeks to answer questions such as: How likely is it that a polluted plume will contaminate the groundwater above the accepted level? This uncertainty needs to be transformed into risk estimates.

The uncertainly related to the remedial action can be described as an uncertainty associated with the performance of a remediation technology. The remedial performance (remediation efficiency and remediation time) will depend on site-specific conditions such as geology and hydrogeology and the parameters describing the location and mass of contaminant. From an economic perspective, the decision maker may have to choose between a remediation technology that has an estimated efficiency of 80 per cent and another more expensive technology that has an estimated efficiency degree of 90 percent. Furthermore, the required time horizon from initiation of remediation to actual protection of the aquifer may be uncertain, especially for in situ remediation technologies in low-permeable settings.

To illustrate the required mapping of risks in an economic analysis we may have to compare the following two types of remediation technologies. Remediation Technology A cleans up the site here and now and Technology B has a time horizon of 15 years. Maybe, Technology A involves handling of highly oxidative reactants for chemical oxidation and implies a risk of spreading new contaminants to the subsurface, whereas Technology B is a gentler remediation technology. Due to the longer timeframe, Technology B will on the other hand imply a larger risk of contaminant spreading during the 15 year timeframe.

The time horizon makes it necessary to weigh costs and benefits of today with costs and benefits in the future. For this purpose the choice of a discount factor is crucial. This is especially important if the time horizon is so long that it will have an implication for future generations.

2.4 Discussion

The policy in Denmark is to remediate sites that pose a risk for pollution of the groundwater above the groundwater quality criteria in areas where the groundwater is or might be used for drinking water supply. This policy may not be attainable as resources are scarce and a prioritisation needs to be done to ensure that the highest risk reduction is obtained at the lowest possible cost. In practice the environment is regulated by the Danish Environmental Protection Act. According to this act the private sector has to remediate on a voluntary basis or on command. If it is not possible to make any people in the private sector responsible for the pollution, the public sector has to prioritise among the projects where remediation is required. Besides prioritisation of cleanup within a catchment, environmental economic assessments can help elucidate the societal benefits and costs of a remediation project. Cost-benefit analyses (CBA) of remediation projects can support decisions on whether a specific remediation project is beneficial to society and should be carried out. A CBA is, however, often quite comprehensive and therefore it is typically the case that a CBA is conducted at only large sites or groups of sites.

Having decided to clean up a certain site, the choice of a remediation technology may depend on a combination of technical considerations (remediation efficiency and time), environmental aspects (secondary impacts quantified in an LCA), remediation costs and political aspects. Assume a situation where different remediation technologies are able to fulfil the defined remedial target. In this case it will be optimal to choose the remediation method that has the least costs and the least secondary environmental impacts. Cost-effectiveness analysis may come in handy in this situation, but will not be able to include the secondary environmental impacts unless these are monetised or the cost-effectiveness analysis is expanded to include other indices e.g. "environmental impact effectiveness". The analysis may then approach a Multi Criteria Analysis.

Multi Criteria Analysis (MCA), sometimes called Multi-Criteria Decision Making (MCDM), is an economic tool which is useful in this situation where the different scores will be evaluated to support decision makers who are faced with conflicting evaluations. MCA highlights the conflicts and derives a way to find a compromise in a transparent process. The prioritisation is based on subjective indicators of the strength of various preferences. These preferences might differ from decision maker to decision maker, so the outcome depends on who is making the decision and what their goals and preferences are.

The timing of the needed expenses for the remediation at a specific site may also be crucial to the choice of solution. Here and now remediation is expensive, but the question is whether the immediate removal of contaminants will help to reduce the risk over time. Enhanced reductive dechlorination, which is an in situ bioremediation method, is an alternative for remediation of chlorinated solvents. This technology requires monitoring on a yearly basis where the expenses will be divided on several years. The fact that it is possible to divide the expenses on several years can look like a more acceptable solution for the politicians who are often focusing on yearly budgets. Furthermore, the discount rate will make future amounts look smaller at present values if the net present value is considered. From an environmental viewpoint other technologies that require a here and now cleaning might reduce uncertainty.

An economic analysis of remediating a site versus not undertaking any action requires that all effects are quantified. The economic analysis may include contributions from technical professionals who have prepared a life cycle assessment and inputs from the public reported in valuation studies. In general the economic analysis has the advantage that all decision criteria are visible and ordered consistently. Any criticism has to relate to this framework and it encourages good arguments to improve the analysis.

Based on the ideas of the economic analyses in this literature review, we will proceed to develop an economic decision support tool to facilitate and prioritise between remediation projects.

3 Literature review

This section describes selected articles where the subject is to remediate soil or groundwater contaminated sites. Normally, there is a wedge between practice and economic tools from the theoretical economic literature. Here the idea is to acquire ideas for specific projects by looking into articles or reports. Please send a mail to my e-mail address: cn@niras.dk if you are aware of some articles that we should include in the following:

Bage, Contran F., Réjean Samson, 2004: "A proactive Approach Can Make Site Remediation Less Expensive". Environmental Management Vol. 34, No. 4, pp. 449-460.

Site/Pollution
A diesel-contaminated site where there has been a leakage of a 25,000-litre diesel tank over an area of 5263 m^2. The contamination has reached a depth of 1.5 m, just above the water table, resulting in a total volume of 7895 m^2 diesel-contaminated soil. Groundwater samples have not revealed any contamination.

A geostatistical study was conducted to report mean concentrations of diesel in mg/kg for each grid of 10 m over 10 m that the site is divided in. There are three possible characterisations of the grid:

1) WS: Diesel concentration lower than 700 mg/kg.
2) MS: Diesel concentration between 700 and 3500 mg/kg.
3) HS: Diesel concentration over 3500 mg/kg.

The first interval is characterised as a weakly contaminated site (WS), the second as a moderately contaminated site (MS) and the third as a heavily contaminated site (HS).

Among the 750 mean values for the grids 98.8% are heavily contaminated and 1.2% are moderately distributed. This is referred to as the initial state of the site (0% WS; 1.2% MS; 98.8% HS).

Economic Tool
A remediation strategy for a diesel-contaminated site has been simulated using a Model for the Evaluation of a Technically and Economically optimal Remediation Strategy (METEORS) developed by Bage and others (2002). The model's main objective is to assess the remediation of a contaminated site on both technical and economic aspects.

Remediation alternatives
1) In situ bioventing
2) Biopile treatment

Costs/unit prices
Capital costs are considered only during the first stage a technology is applied, whereas Operation & Maintenance costs are considered at every stage where the technology is used.

Goals
To improve the initial state of the site reaching a higher proportion of the soil that is less contaminated. The effectiveness of the remediation technologies is measured by the annual mean reduction in concentration over a simulation stage (i.e. one year).

Decision-making for choice of remediation technology
The output of the model is a remediation strategy that guides, year after year, the selection of the most optimal technology considering the evolution of the

remediation. At the beginning of each stage during a simulation, METEORS chooses between three alternatives:

1) selecting the most appropriate technology without reducing the uncertainty about the true site situation;
2) acquiring more information through additional characterization prior to technology selection;
3) stopping the remediation.

The decision taken is the one with the highest economic value, which is a function of all values in subsequent stages.

Ranking the remedial alternatives

The optimal remediation strategy is dependent on the state of the site (i.e. WS, MS or HS). A simulation in the model METEORS results in some scenarios from which an optimal remediation strategy can be found. A risk index (RI) can be defined as the ratio between the standard deviation of all scenario values of a strategy and the value of the strategy. This index is used to quantify the risk that a scenario value may be quite different from the strategy value as the strategy leads to a unique scenario among all the scenarios that compose the strategy.

When two or more Optimal Remediation Strategies are obtained for the same site, comparing both the ORS values and their RIs can guide the selection of the most preferred ORS.

Beinat, E. et. Al. (1997). The REC decision support system for comparing soil remediation options. A methodology based on Risk reduction, Environmental merit and Costs.
CUR/NOBIS report.

Site

Soil remediation – cleaning soil and groundwater.

Pollution

Different categories of contaminants. The Soil Protection Guidelines (1997, Section A 2.2) contain factors used to standardise contaminant concentrations. These guidelines distinguish intervention values and target values. Intervention values are generally based on both human toxicological and eco-toxicological effects.

Economic Method

The selection of a remediation alternative is a multiobjective problem where REC plays the role as a decision support system. Ideally, the alternative selected is that which maximises risk reduction (R), environmental merit (E) and minimises costs (C). However, in practice such an alternative is rare, and therefore the final selection is usually based on weighing the advantages and disadvantages of each remedial alternative. The indices for R, E and C in the REC methodology yield the required information for such a weighing.

Remediation alternatives

1) Multifunctional option (MF): Soil excavation and groundwater extraction.
2) The Isolation and Control Management option (ICM):
3) The In Situ option (biological remediation):

An example case where the contamination consists of chlorinated solvents from a former dry-cleaning company illustrates the method throughout the REC report. For this example case, the MF provides a high risk reduction and an environmental merit at high costs. The ICM is the cheapest solution, but the method has a significantly inferior risk reduction and a negative environmental merit balance. The In Situ option yields a high risk reduction and intermediate environmental merit performance at rather low costs.

It is possible to make explicit decision rules for the choice of a remediation alternative. Different sets of weights for the R, E and C indices can for example illustrate different criteria for a solution of a remediation alternative for a specific site.

Costs/unit prices

Financial costs to carry out the remediation. For each remediation alternative, the cost estimate is based on Expected Costs and standard deviation.

Uncertainty about costs:

1) The volume of contaminated soil
2) The degree to which the soil is contaminated
3) Conversion from the quantity of soil to weight.
4) The accuracy of the geohydrological model used to describe soil features.

5) The velocity at which the contamination moves.
6) The duration of the remediation project.
7) The effectiveness of the remediation technology applied.
8) The moment when the remediation project will be commenced.
9) The costs of soil processing.

Goals

REC extends the traditional single perspective evaluation and focuses on the full balance sheet of remedial operations by evaluating the Risk reduction, Environmental merit and Costs of operation where

Risk: Reduces risk for humans, ecosystems and other targets at site. Exposure models like CSOIL are the most suitable for assessing risk reduction. The REC methodology bases the risks estimates on a Risk Index (RI), which is the ratio between the exposure and the toxicological limit value linked to a target (i.e. the derivation of the standardised exposure of humans can be RI = exposure as a result of soil contamination/Tolerable Daily Intake). For soil contamination, the limit values are the Tolerable Daily Intake (TDI) for human health; the 50% Hazard concentration for ecosystems and a concentration to which a specific effect can be linked for other objects.

Environmental merit: Increases the stock of clean soil, increases the stock of clean groundwater and prevents groundwater contamination. Secondary effects such as loss of soil, energy consumption, air emissions etc. are also evaluated. A panel of experts attaches weights to the different aspects of environmental merit. These weights are used to calculate a score for the overall environmental merit of a remediation alternative.

Costs: Use of scarce resources, transfer contamination to other media and financial costs to carry out the remediation.

Decision-making for choice of remediation technology

The decision maker can balance effectiveness and efficiency of different remediation alternatives. A focus on effectiveness will select the most effective option provided the budget available is sufficiently high (the MF option); A focus on costs will select the cheapest solution provided some significant risk reduction is achieved (the ICM option); A focus on efficiency will select the solution which gives the best ratio between risk reduction, environmental merit and costs (the In Situ option).

REC is a decision-support system. Ideally, the alternative is selected that minimises risk reduction and environmental merit and minimises costs (i.e. the REC indices). However, in practice such an alternative is rare, and therefore the final selection is usually based on weighing the advantages and disadvantages of each remedial alternative. In some cases the REC indices are adequate for making a decision and in other cases other factors play a role in the decision-making process.

Although sensitivity analysis is not included as a default part of REC, carrying out a sensitivity and uncertainty analysis for R and E in particular is a prerequisite for making robust evaluations.

Ranking the remedial alternatives

A decision rule can be applied that has to weigh the relative importance of R, E and C.

The REC criteria were preferred to LCA partly in order to maintain a clear distinction between Environmental merit and Risk reduction, although the various inputs and outputs of the remediation process can be listed in a similar way for LCA.

Experts have established weights to the environmental merits of the alternatives. These weights can be weighed differently to derive an environmental merit index.

Khadam, I. M. & Kaluarachchi, J.J. (2003).
Multicriteria decision analysis with probabilistic risk assessment for the management of contaminated water.

Environmental Impact Assessment Review 23 (2003) 683-721.

Site
A subsurface contamination that contaminates ground water resources.

Pollution
The demonstration example described in the article uses an aromatic hydrocarbon constituent, benzene, which is a carcinogen. However, the authors write that the methodology can be easily applied to sites with dissolved plumes of industrial solvents, such as trichloroethylene (TCE) or similar carcinogens, through proper representation in the risk assessment and hydrogeologic analysis.

Economic Method
Multicriteria Analysis that also encompasses a Cost Effective Analysis.

The authors of this article find that there are limitations associated with a Cost Benefit Analysis, especially its definition of risk, its definition of cost of risk, and its poor ability to communicate risk-related information.

Remedial alternatives
The remedial alternatives in the demonstration example include simple configurations of pump-and-treat (PAT) with injecting well. The simplest alternative is the no-action alternative which allows the plume to be destroyed through natural attenuation. Other alternatives include different combinations of PAT and two involving enhanced biodegradation using oxygen injected into the plume. Air stripping is used to clean the contaminated ground water extracted from the PAT operations. This simple configuration facilitates the optimization of the well locations using a trial and corrections process without the use of a sophisticated optimization analysis.

Costs/unit prices
Values of Costs Per Life Saved (US$m).

The cost of remediation for each alternative was estimated using Tank RACER software, which was developed for the US department of Defence. Later on Tank RACER has been used by state and local agencies to determine the costs of cleanup on a site-specific basis. The costs include the capital, operation and maintenance, and sampling costs.

Goal
The paper presents an integrated approach for management of contaminated ground water resources using health risk assessment and economic analysis through a multi-criteria decision analysis framework. The methodology focuses on developing decision criteria that provide insight into the common questions of the decision-maker that involves a number of remedial alternatives. The applicability of the proposed decision analysis methodology is presented in a demonstration example.

Decision-making for choice of remediation technology

The immediate objectives of a decision-maker, faced with a subsurface contamination situation, typically include:

(a) reducing the cancer risk to the exposed population to the extent feasible

(b) minimizing legal liability by complying with the acceptable risk established by the regulators.

(c) minimizing the cost of the corrective measures (i.e. reasonable CPLS).

The proposed methodology introduces five decision criteria:

(1) maimum individual risk

(2) expected individual risk

(3) population risk

(4) risk index

(5) cost per cancer case avoided or cost per life saved.

The health risk has the following pathways: 1) Ingestion of water, 2) Inhalation of volatiles, 3) Dermal contact. All the risk indices depend on both uncertainty and variability in a 3-D risk surface. The maximum individual risk measures the lifetime risk at an upper limit of the uncertainty and variability. The expected individual risk calculates the average risk over the uncertainty holding the variability fixed at the 95th percentile, which corresponds to picking a maximum exposed individual in the population. The population risk is the number of expected cancer cases in the exposed population per year. The risk index describes the trade-off between the individual and population risks based on observations from published regulatory data. This RI was introduced by the authors as they do not see themselves in a position to judge in the ethical question whether the collective welfare of the society is more important than the welfare of the most vulnerable individual in the population or not. Finally, the cost per life saved is a measure of the cost-effectiveness of a remedial alternative per unit risk reduced (i.e. the CPLS is used to convey to the decision-maker how costs are being employed to reduce risk). In other words the criterion of CPLS is a way to address the trade-off between cost of remediation and the corresponding risk reduction.

Ranking the remedial alternatives

An explicit decision analysis is a two-stage approach that has a filtering stage followed by a selection stage. The filtering stage rejects the alternatives that do not match the decision criteria. The filtering stage requires that all the remediation alternatives possess justification for implementation given the three above objectives for the decision maker. For instance, alternatives with low CPLS are more preferable than those with high CPLS while achieving similar cleanup targets and risk reduction. In this case a high CPLS indicates inefficient management of the contamination event. The selection stage ranks the filtered alternatives according to the increased cost due to the reduction in risk from one alternative compared with another alternative for the final selection.

The implicit decision analysis defines the decision criteria that are applicable to all alternatives in the first place. The method performs a one-step process to rank all the alternatives based on the decision criteria (i.e. the implicit method does not attempt to study each alternative separately to measure its compliance with the decision objectives as the explicit method). Two mathematical methods for ranking alternatives are used, and these are the importance order of criteria (IOC) method and the fuzzy dominance and resemblance (FDR) method. The (IOC) method assumes an additive utility function that assigns weights to the decision attributes. The total utility of an alternative is the simple arithmetic sum of weighted attributes. The assignment of numerical scores and weights in the (IOC) method is highly subjective and reflects the risk-aversion, preferences, and policies of the decision-maker that may change with time. The methods based on the fuzzy set theory (i.e. the Fuzzy dominance analysis and the Fuzzy resemblance analysis) set up a decision matrix that contains the remedial alternatives in the rows and the decision criteria in the columns. This decision matrix can also be transformed by assigning weights to the decision criteria where each decision criteria is normalised between 0 and 1. The Fuzzy dominance analysis uses the matrix to rank the alternatives based on the dominance relationships between pairs of alternatives (i.e. it performs a pair-wise comparison of the alternatives). Alternatives with adjacent positions in the ranking list may or may not be similar. This is the first task, which is called Level 1 analysis. The Fuzzy resemblance analysis is an additional layer, which is called Level 2 analysis. The Fuzzy resemblance method uses the decision matrix to identify the degree of similarity among the remedial alternatives. Thus, it is possible to identify how remedial alternatives are likely to be clustered).

Lemming, Gitte, Peter Friis-Hansen and Poul L. Bjerg, 2009.
Risk-based economic decision analysis of remediation options at a PCE-contaminated site.

Journal of Environmental Management 91 (2010) 1169-1182.

Site

A site in Denmark which is heavily contaminated with chlorinated ethenes. The site is situated within the groundwater catchment of the largest Danish well field located approximately 2000 m down gradient from the site. Groundwater is the sole source of drinking water in this area and therefore represents a scarce and valuable resource.

Pollution

The mass of chlorinated solvents is estimated at 10 tons and primarily in the form of tetrachloroethene (PCE).

Economic Method

The economic analysis combines assessments of health risk and environmental impacts. The paper focuses on human health costs associated with the potential ingestion of contaminated drinking water, which is dependent on the remediation alternatives. The human health risk cost is estimated using the Life Quality Time Allocation Index. Environmental impacts caused by the remedial activities are evaluated using life cycle assessments (LCA) of each remediation scenario.

Remediation alternatives

(a) No action
(b) Excavation and off-site treatment of soil
(c) Soil Vapor Extraction
(d) Thermally enhanced soil vapour extraction

Costs/unit prices

Health costs as a cause of the contaminant concentrations is given by a probalistic exposure model. The health effects due to intake of contaminated drinking water are estimated assuming a linear dose-response function for the increased lifetime cancer risk and a health cost is derived based on incurred costs of averting a fatality or incurred costs of averting an injury. Environmental emissions and resource consumption are normalized to person equivalents and weighted to a single index. A simple monitization of the weighted environmental impacts and resource consumption is done assuming that each weighted impact/resource use represents the same cost.

Goal

To present a methodology for an integrated economic decision analysis which combines assessments of remediation costs, health risk costs and potential environmental costs. The paper illustrates contaminant concentrations, remediation costs, environmental costs and health costs for the four remedial alternatives.

Decision-making for choice of remediation technology

The analysis in the article finds that the most important variables depend on whether a no action scenario or a remediation scenario is considered. For the no action scenario, important variable uncertainty is associated especially with the characterization of the source area represented by the source zone contaminant concentration, the presence of residual phase contamination and the size of the contaminated area. In addition the infiltration rate to the aquifer is of high importance. In the three remediation scenarios, the remediation efficiency is by far the single most dominating cause of uncertainty.

Ranking the remedial alternatives

The four cases are ranked based on their total societal costs. It is possible to conduct sensitivity
analyses by changing for instance the incurred cost of averting a fatality.

Wang, Mingyu (2006):
Environmental Assessment
Optimal Environmental Management Strategy and Implementation for Groundwater Contamination Prevention and Restoration.

Environmental Management Vol. 37, No. 4, pp. 553-566.

Site
Contaminated sites that expose a threat to groundwater systems.

Pollution
The major threats are sites where there are underground storage tanks, septic tanks, agricultural activities, municipal landfills, and abandoned hazardous waste sites. Other threats include industrial landfills, injection wells, road salt, saltwater intrusion and brine pits from oil and gas wells.

Economic Method
The applied method in this paper is linear programming which is a Cost Effective Analysis approach. The objective function in the linear programming problem maximises the risk reduction on existing contaminated sites given costs of investigation and remediation and on the projected sites given costs of investigation and prevention. The objective function reaches its maximum while constraints (i.e. CAP resources for investigation and remediation at contaminated sites and investigation and prevention at projected sites as well as some restrictions on total costs) are satisfied.

Furthermore, the paper sets up an objective function for the year-by-year optimizations for a certain year in a number of years.

Remediation alternatives
- A pump-and-treat remediation measure
- Natural attenuation

Costs/unit prices
Six different categories of costs are identified with regard to groundwater prevention and restoration (uncertainty from Aquifer Heterogeneity).

Goals
To maximise risk reduction including human cancer risks, human noncancer risks and ecologic risks.

Decision-making for choice of remediation technology
To manage groundwater efficiently, the author believes that it is imperative to devise a proper environmental management strategy in order to maximize resource or budget utilisation, minimise adverse impacts on the environment and pursue the sustainable development. The optimal environmental management strategy is based on the integration of four critical components:

1) environmental impacts including human health and ecologic risks from groundwater contamination.
2) availability of the resources including financial resources and personnel for groundwater contamination prevention and restoration.
3) Beneficial uses and values including economical and social values from groundwater protection.

4) Sustainable development.

Ranking the remedial alternatives

Determination of the optimal solution for the site selections by an optimization tool.

Wang, Todd A. and William F. McTernan

The development and application of a multilevel decision analysis model for the remediation of contaminated groundwater under uncertainty.

Journal of Environmental Management (2002) 64, 221-235.

Site

Example problem: Texas near the Louisiana border. The methodology is generic in nature in that I can be applied to any location where groundwater remediation is being contemplated.

Pollution

TCE was present in significant amounts and could migrate through a potentially usable aquifer. The amount of TCE detected in the groundwater exceeded the national drinking water standards of 5 µg/l. TCE was therefore chosen as the example constituent against which the Decision Model was formulated.

Economic Method

Linear programming where the objective function is to minimise costs consisting of a remedial action cost function, a risk failure cost function, an additional testing cost function and a monitoring well cost function.

This paper applies the decision analysis methodology (DAM) that links a classic decision making modelling approach with stochastic economic and environmental simulation to identify an optimum remediation decision given uncertainties in fundamental physical, chemical and economic information.

Remediation alternatives

- Bioremediation
- Pump and treat alternative
- No action

Costs/unit prices

Capital, operational and maintenance costs for all functions were determined using the EPA's Cost of Remediation Alternatives (CORA) software (CH_2MHILL, 1990).

- Remedial action cost function
- Risk failure cost function
- Additional testing cost function
- Monitoring well cost function

Costs associated with treating and discharging the extracted groundwater were developed. Two types of treatment were evaluated: activated carbon adsorption and air stripping.

Goals

To address questions such as:

1) Is remediation necessary?
2) When should remediation start?
3) What type, if any, remediation technique(s) should be employed?

"The primary objective of the reported work was to develop an inclusive, integrated aquifer remediation decision model that utilized state of the art mathematical and statistical methods to define contaminant risk to potential users of the impacted resource. In this manner, the optimum alternatives defined by the decision model were based on scientifically defensible techniques for contaminant analysis. A second objective was to apply the developed model to a location where decision making had previously proven difficult, where complex geology, hydrology and chemistry served to undermine confidence in suggested remediation alternatives. "

Decision-making for choice of remediation technology

Decision tree analysis. The example problem presents a 'take' or 'postpone action' alternative to the decision maker. Postponement can be for budgetary reasons, better site assessment or others. If 'take action' is chosen, then subsequent decisions involve additional testing and remedial action followed in the decision tree. The same questions involve remedial action following the postponement decision.

A plane of compliance (POC) was established to identify potential receptors to the contaminant of concern. The POC for the case existed along an interface between the groundwater and the surface water. The base case for decision making was that any TCE excursion ≥ 5 µg/l that reached the POC would be considered failure and that costs would be incurred. Expected monetary values are calculated for all the scenarios in the decision tree.

Ranking the remedial alternatives

The ranking was dependent on whether a contamination ≥ 5 µg/l was detected or not.

Weber, Klaus, Gitte Lemming, Nils Wodschow, Christian Zilstorff Munch-Andersen, Carsten Bagge Jensen, Ole Kiilerich, Kim Sørensen and Mads Terkelsen
Remediation Strategy for Soil and Groundwater Pollution RemS – A Decision Support Tool.
Paper presented at the Green Remediation Conference November 9-10, 2009 in Copenhagen, Denmark.

Site
RemS is intended to be used in the planning phase for soil and groundwater remediation projects on the site specific level.

Pollution
Soil and groundwater pollution.

Economic Method
Cost effective analyses.

Net Present Values allow a comparison of alternative strategies with different payment profiles over time.

Goals
To support the decision making process by systemising and documenting the workflow and quantificating the most important decision parameters. It helps the user to maintain an overview of the decision parameters through the project planning process.

Decision-making for choice of remediation technology
RemS is a decision support tool to assist in the planning and projecting phase when remedial techniques and strategies are decided on a specific site.

All remediation strategies are summarized in a matrix versus all decision parameters for an easy overview. A score system is included to give an easy overview of the relative difference between decision parameters and between remediation strategies. A user score based ranking of the remediation strategies is possible.

Ranking the remedial alternatives
RemS strengthens the decision making process and makes the process more transparent to cooperators and customers as the reporting facilities ease communication to politicians and stakeholders. Furthermore, a score system is optional for an easy identification of the best remediation strategy.

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Appendix

CURRENT NETWORKS

This section provides an overview of the current organisations that serve as networks to assist in soil and groundwater contamination. The following presents extracts from homepages of different organisations, such as NICOLE, SuRF UK, together with comments to provide an overview of the state of the art nowadays.

NIRAS held a Green Remediation Conference in Copenhagen 9-10 November 2009 where several examples of ongoing remediation projects were presented.

Common Forum on Contaminated Land

http://www.commonforum.eu/

The COMMON FORUM on Contaminated Land, initiated in 1994, is a network of contaminated land policy makers and advisors from national ministries in European Union memberstates and European Free Trade Association countries.
It introduced "Risk Based Land Management" as a central concept in European contaminated land approaches and demonstrated that European Union wide harmonisation can arise if all stakeholders realise the benefits of this, even without a formal European Union policy.

CLARINET (developed concept for RBLM)

Darmendrail (2009) writes that some experienced countries have developed a risk based land management approach (RBLM). RBLM includes a sustainable solution design, which integrates spatial planning, soil & water management and socio-economy issues. Bardos (2009) writes that RBLM is primarily a framework for the integration of two key decisions for remediation of contaminated land:

The time frame: this requires an assessment of risks and priorities, but also the consideration of the longer term effects of particular choices.
The choice of solution: this requires an assessment of overall benefits, costs and environmental effects, value and circumstances of the land, community views and other issues.

Darmendrail (2009) finds that there is a need for a common protocol for choosing the appropriate models or the best sustainable remediation technologies. Furthermore, there is a need for collaboration and cooperation on political issues.

Bardos (2009) writes that the "CLARINET was a "Concerted Action" of the European Commission's Environment and Climate Research and Development Programme. The project ran from 1998 to 2002 and was funded and supported by the European Union and by national agencies and regulators. Its primary objectives were to develop technical recommendations for sound decision making on the rehabilitation of contaminated sites in Europe and to identify research and development needs. Some of these ideas were transmitted by wider international networks and meetings established under the NATO Committee for Challenges to Modern Society (US EPA 2000) and ultimately began to influence thinking in the US EPA. It may be a stretch to assume that the US EPA concept of "green remediation" (US EPA 2008) had its origins in NATO/CCMS, but the Pilot Studies can only have helped!"

NICOLE (Network for Contaminated Land in Europe)
WWW.NICOLE.ORG

NICOLE was set up in 1995 following an initiative from the European Chemical Industry Council (CEFIC). NICOLE is the principal forum where industry, service providers and academia cooperate to develop and influence the state of the art in contaminated land management in Europe. NICOLE was created to bring together problem holders and researchers throughout Europe who are interested in all aspects of contaminated land. It is open to public and private sector organisations. NICOLE was initiated as a Concerted Action within the European Commission's Environment and Climate RTD Programme in 1996. It has been self-funding since February 1999.

NICOLE's overall objectives are to:

Provide a European forum for the dissemination and exchange of knowledge and ideas about contaminated land arising from industrial and commercial activities;

Identify research needs and promote collaborative research that will enable European industry to identify, assess and manage contaminated sites more efficiently and cost-effectively; and

Collaborate with other international networks inside and outside Europe and encompass the views of a wide a range of interest groups and stakeholders (for example, land developers, local/regional regulators and the insurance/financial investment community).

NICOLE prefers to provide a Road Map that can be used to aim for increased sustainability in site remediation decision making in stead of offering a prescriptive and dogmatic view on tools and indicators (Maurer, 2009). The useful tools in the decision making are: a series of checklists to provide technical support to decision-makers, allowing them to examine suggestions of possible sustainability criteria or factors (indicators) and to provide available tools and techniques in the literature or on the market along with some assessment of their utility.

CH2 (France) is leading a NICOLE working group on sustainable remediation (SRWG). The group is defining what sustainable remediation (SR) principles actually mean, what tools are available, and importantly, which are really feasible. The SRWG was initiated in October 2008, during the workshop in Madrid on decision tools and has since been very active (NICOLE news, October 2009).

Bardos (2009) describes how the Brundtland Report concept of sustainable development can be linked with risk based land management as a tool in decision making. The "most sustainable" approach is one that, in the view of the stakeholders involved in making or considering management decisions, has the optimal balance of effects for each of the three elements of sustainability: environment, economy and society.

CL:AIRE
http://www.claire.co.uk/

CL:AIRE is an independent, not-for-profit organisation, established to stimulate the regeneration of contaminated land in the UK by raising awareness of, and confidence in, practical sustainable remediation technologies.

CL:AIRE encourages technology demonstration and research projects to raise industry's awareness of, and confidence in, technologies that have been applied on real sites. From these projects, CL:AIRE can provide all those with an interest in ***contaminated land*** with documented, high-quality, and scientifically-robust demonstration reports that appraise available ***remediation technologies***. CL:AIRE's aim is to build a portfolio of these technology demonstration and research projects using different technology providers demonstrating under different conditions to show successes as much as lessons learnt, so that a thorough understanding of the application of a technology can be achieved. To do this, we actively seek the participation of site owners, consultants, developers, ***remediation*** companies and technology providers to become project partners. We accept a variety of projects which are evaluated on their technical merits by our ***Technology and Research Group*** against a transparent set of criteria.

Sustainable Remediation Forum – UK (SuRF UK) is a Steering Group under the co-ordination of CL:AIRE. The objective of SuRF UK is to develop a framework in order to embed balanced decision making in the selection of the remediation strategy to address land contamination as an integral part of sustainable development.

The deliverable of SuRF UK is a framework, as opposed to a tool or model. In using the word 'balanced' the mission statement means for a framework to consider social, environmental and economic factors. 'Strategy' is meant to include the design and implementation phase of a remediation project whilst 'Land contamination' is meant to capture related groundwater issues. 'Development' is meant in a wider context of sustainable development as opposed to the narrower meaning of a property development scheme.

NICOLE SRWG and SURF-UK join efforts

In September 2009, after NICOLE was being invited by SuRF UK, the two organizations decided to join their efforts (Maurer, 2009):

"What is interesting about this collaboration is the complementarily of the SuRF-UK framework and the NICOLE Road-Map. The SuRF UK framework essentially addresses the question of "when" sustainability should be considered (in a UK context). The NICOLE Road-map considers "how" sustainability should be used as a decision-making criterion. The "when" may be affected by national or regional considerations, the "how" is more generic. It therefore seems likely that there is a good opportunity for the cross-fertilization of ideas."

Economics was considered to be one of five important strands at least by NICOLE in October 2008 that also encompasses communication, risk management, indicators and case studies. Moreover, (Maurer, 2009) writes the following about Economics:

"Based on sustainable development principles, SR is all about the "triple bottom-line", balancing between environmental, social and economic aspects. Remediation practitioners understand well the technical implications of environmental issues but as said before often lack experience with social and economic issues. A number of tools, standards, and methodologies are widely used such as Net Benefit Analysis (NBA), Life Cycle Analysis (LCA), Best Available Technology Not Exceeding Excessive Cost (BATNEC), and guidance on using these tools in the application of SR is necessary."

At the meeting in September 2009, the Risk Assessment Subgroup concluded that there is no clear consensus on the interrelationship between SR and risk assessment (Maurer, 2009). "For SR to be effectively and materially implemented, policy makers and regulators will need to be allowed to integrate it with the concepts of risk assessment, without undermining the principles of human health and ecological protection."

Bardos (2009) writes: "NICOLE SRWG and SURF-UK are collaborating to develop a ***check-list*** of sustainability indicators that can be considered by individual projects to identify those seen as relevant, and perhaps combine them with indicators seen as important for policy and corporate reasons. A key point is that the final set of attributes of sustainability that will be considered must represent a consensus view of all of those who will be considering the outputs of the sustainability appraisals. If you cannot agree on the findings of the sustainability appraisal!"

In the discussion Bardos goes on writing: "The major differences in approach between these initiatives are related to execution, in two ways:

1. the extent to which an overarching framework is deemed necessary to achieve sustainability benefits from better practise in remediation; and

2. the breadth and scope of factors which should be considered – some argue that sustainability appraisal should be wide ranging, and others argue that it should be constrained to a limited number of readily quantifiable metrics."

Surf US

There is also a Sustainble Remediation Forum in the USA. Their mission of SURF is to establish a framework that incorporates sustainable concepts throughout the remedial action process while continuing to provide long-term protection of human health and the environment and achieving public and relatory acceptance.

SURF US has prepared a document to collect, clarify, and communicate the thoughts and experiences of the SURF membership on the incorporation of sustainability concepts and principles into remediation. As such, the document is a platform from which individual SURF members can share the collective thinking of the group with others (Ellis and Hadley, 2009).