A web-based decision support tool for groundwater remediation technologies selection

Olfa Khelifi, Andrea Lodolo, Sanja Vranes, Gabriele Centi and Stanislav Miertus

ABSTRACT

Groundwater remediation operation involves several considerations in terms of environmental, technological and socio-economic aspects. A decision support tool (DST) becomes therefore necessary in order to manage problem complexity and to define effective groundwater remediation interventions. CCR (**C**redence **C**learwater **R**evival), a decision support tool for groundwater remediation technologies assessment and selection, has been developed to help decision-makers (site owners, investors, local community representatives, environmentalists, regulators, etc.) to assess the available technologies and select the preferred remedial options. The analysis is based on technical, economical, environmental and social criteria. These criteria are ranked by all involved parties to determine their relative importance for a particular groundwater remediation project. The Multi-Criteria Decision Making (MCDM) is the core of the CCR using the PROMETHEE II algorithm.

Key words | decision support tool, groundwater remediation, multi-criteria decision making, outranking methods

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INTRODUCTION

Decision-making on groundwater management issues is often a process characterized by complexity, uncertainty, multiple and sometimes conflicting management objectives, as well as integration of numerous and different data types. For these reasons, it is important that policy-makers, engineers and the general public have proper information so that the current situation can be evaluated, trends identified and ways can be found to a more sustainable future.

In environmental management, it has been shown that multi-criteria analysis can be effective in increasing the understanding, transparency, acceptability and robustness of a decision (Beinat 2001). The aim of a multi-criteria problem is to lead to a concrete decision, not an optimal solution that is better than all other alternative for all the criteria (utopia point) and leads to a mathematically ill-defined problem, but to find a compromise solution, i.e. an alternative that is better for most of the criteria (Vincke 1992).

A variety of mature and emerging groundwater remediation technologies is available and future trends in the groundwater remediation industry will include continued competition among environmental service companies and technology developers, which will definitely result in further increase in the cleanup options. Consequently, the demand has developed for a decision support tool build on Multi-Criteria Decision Making (MCDM) that could help the decision-makers to select the most appropriate technology for the specific contaminated groundwater resource, before costly remedial actions are taken.

Therefore, the first prototype of CCR (Credence Clearwater Revival), a decision support tool (DST) for groundwater remediation technologies assessment and selection, has been developed to improve the decision-making ability of managers, investors, environmentalists and other stakeholders by allowing faster or better decisions within the constraints of cognitive, time, regulatory and economic

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limits. CCR is a Web-based decision support tool and will be accessible through the internet for beneficiaries' institutions from all over the world. This paper first presents the MCDM methods and their applicability in DSTs, then the methodology used to develop the CCR decision support tool and, finally, a demonstration of the implemented prototype is presented.

MCDM METHOD SELECTION

In order to support the decision-maker who must solve multi-criteria problems, three kinds of MCDM methods were essentially considered: aggregation methods using utility functions, interactive methods and outranking methods. The last ones were used in the present work (actually special outranking methods): ELECTRE and PROMETHEE (PROMETHEE I, providing a partial preorder, and PROMETHEE II, providing a total preorder on the set of possible decisions), because of their popularity among people who are not experts in the field. Outranking methods represent binary relations between alternatives, given the preference of the decision-maker, the quality of the valuations of the alternatives and the nature of the problem (Vincke 1992).

A few preliminary remarks and definitions are in order. A problem of multi-criteria decision-making is usually formalized by means of a set of alternatives $A=\{a, b, c,\ldots\}$ and a set of functions-criteria $\{g_1, g_2, g_3, \ldots, g_n\}$; here, the criteria are real-valued functions defined on a set A so that $g_i(a)$ represents the performance or the evaluation of the alternative $a \in A$ on criterion g_i; the higher the evaluation, the better the alternative satisfies the criterion in question. Consequently, the multi-criteria evaluation of alternative a is the vector $g(a) = (g_1(a), \ldots, g_n(a))$ comprised of partial evaluations of n criteria.

ELECTRE methodology

ELECTRE uses the concept of an 'outranking relationship'. This method consists of a pairwise comparison of alternatives based on the degree to which evaluations of the alternatives and the preference weights confirm or contradict the pairwise dominance relationship between alternatives. It examines both the degree to which the preference weights are in agreement with pairwise dominance relationships and the degree to which weighted evaluations differ from each other. These stages are based on a 'concordance and discordance' set. The valued outranking relation of the ELECTRE method is characterized by the definition of an outranking degree $S(a, b)$ associated with each ordered pair (a, b) of alternatives, representing the more or less large outranking credibility of a over b. A weight p_j having been associated with each pseudo-criterion g_j, the following concordance index is computed for each ordered pair (a,b) of alternatives:

$$c(a,b) = \frac{1}{P} * \sum_{j=1}^{n} p_j c_j(a,b) \quad \text{where } P = \sum_{j=1}^{n} p_j$$

and where

$$c_j(a,b) = 0 \text{ if } g_j(b) - g_j(a) \geq p_j[g_j(a)]$$

$$c_j(a,b) = 1 \text{ if } g_j(b) - g_j(a) \leq q_j[g_j(a)]$$

$$0 \leq c_j(a,b) \leq 1 \text{ if } q_j[g_j(a)] < g_j(b) - g_j(a) < p_j[g_j(a)]$$

the q_j and p_j denoting the indifference and preference thresholds, respectively.

$C(a, b)$ represents, in a manner of speaking, the percentage of weights of the criteria that concord with the proposition "a outranks b".

The definition of discordance requires the introduction of a *veto threshold* $v_j(g_j(a))$ (a function of $g_j(a)$) for each criterion j such that any credibility for the outranking of b by a is refused if

$$g_j(b) \geq g_j(a) + v_j(g_j(a))$$

the latter even if all other criteria are in favour of the outranking of b by a.

A discordance index, for each criterion, is then defined by

$$D_j(a,b) = 0 \text{ if } g_j(b) - g_j(a) \leq p_j[g_j(a)]$$

$$D_j(a,b) = 1 \text{ if } g_j(b) - g_j(a) \geq v_j[g_j(a)]$$

and it is linear between two.

A great advantage of the ELECTRE-type methods is that the comparison of alternatives is partial, given the fact that the criteria retain their intrinsic properties and can 'refuse' certain comparisons (discordance effects). This phenomenon can occur in either direction for a given pair of alternatives (a, b) and can lead to the proposition 'a is incomparable to b', in other words, there is non-outranking in either direction.

Suppose, in fact, that for (*a*,*b*), $C(a, b) = 1$; this means that $g_i(a) - g_i(b) \geq 0$ for each *i*. On the other hand, for $C(a, b) < 1$, there is at least one criterion *j*, such that $g_j(b) - g_j(a) > 0$ if this inverse difference is too great and this is beyond a veto threshold v_j $(g_j(b) - g_j(a) \geq v_j)$, the proposition '*a* outranks *b*' is definitely refuted and criterion *j* is thus certainly discordant to this proposition. This phenomenon corresponds to a nul-outranking; thus if non-outranking occurs in the other direction as well the two alternatives can be said to be incomparable.

Finally, the degree of outranking is defined by

$$S(a,b) = c(a,b) \text{ if } D_j(a,b) \leq c(a,b), \quad \forall j$$

or

$$S(a,b) = c(a,b) \prod_{j \in J(a,b)} \frac{1 - D_j(a,b)}{1 - c(a,b)}$$

where $J(a, b)$ is the set of criteria for which $D_j(a, b) > c(a, b)$.

The degree of outranking is thus equal to the concordance index when no criterion is discordant; in the opposite case, the concordance index is lowered in function of the importance of the discordances.

PROMETHEE methodology

Numerous practical applications of the PROMETHEE method have shown that it is very easily accepted and understood by practitioners, being the easiest approach for solving a multi-criteria problem by considering simultaneously extended criteria and outranking relations. These extended criteria can be easily defined by the decision-maker, because they represent the natural notion of the intensity of preference and the parameters to be fixed (a maximum of 2) have a real economic meaning. The extension is based on the introduction of a preference function, giving the preference of the decision-maker for an alternative *a* with regard to *b*. This function is defined separately for each criterion, where its value is between 0 and 1. The smaller the function, the greater the indifference of the decision-maker; the closer to 1, the greater his preference. In the case of strict preference, the preference function is 1. A preference function, $P_h(a,b)$, is usually represented by a function $p(x)$:

$$p(x) : x \rightarrow [0, 1] \text{ and } x = f(a) - f(b)$$

where $f(a)$ and $f(b)$ represent the values of a particular criterion, *h*, for alternatives *a* and *b*, respectively. Six different $p(x)$ functions are presented in Figure 1.

Using a preference index, $\pi(a, b)$, the preference for *a* with regard to *b* over all criteria can be determined:

$$\pi(a, b) = \frac{1}{\sum_{h=1}^{k} W_h} \sum_{h=1}^{k} W_h P_h(a, b)$$

where *k* represents the number of criteria, W_h is a weight for the criterion *h* and $P_h(a, b)$ is the preference function for the criterion *h*.

A *valued outranking graph* consists of nodes represented by actions and arcs, where each arc (a, b) has a value $\pi(a, b)$ (Figure 2).

When obtained, the *valued outranking graph* offers a decision-maker the means for determining a partial preorder (PROMETHEE I) or a total preorder (PROMETHEE II).

In order to rank the alternatives by a partial preorder, the outgoing flow must be evaluated:

$$\phi^+(a) = \sum_{x \in K} \pi(a, x),$$

where *K* is the set of all alternatives, and the incoming flow:

$$\phi^-(a) = \sum_{x \in K} \pi(x, a).$$

The outgoing flow $\phi^+(a)$ describes the degree to which *a* dominates the other alternatives in *K*, while the incoming flow $\phi^-(a)$ represents the degree to which *a* is dominated. Using the outgoing and incoming flows, the two total preorders (P^+, I^+) and (P^-, I^-) can be defined, such that:

$$a P^+ b \text{ iff } \phi^+(a) > \phi^+(b),$$
$$a P^- b \text{ iff } \phi^-(a) > \phi^-(b);$$

$$a I^+ b \text{ iff } \phi^+(a) = \phi^+(b),$$

$$a I^- b \text{ iff } \phi^-(a) = \phi^-(b).$$

Then the partial preorder $(P^{(1)}, I^{(1)}, R)$ can be determined by considering their intersections:

$$\begin{cases} a \text{ outranks } b (a P^{(1)} b) & \text{iff} \begin{cases} a P^+ b \text{ and } a P^- b, \\ a P^+ b \text{ and } a I^- b, \\ a I^+ b \text{ and } a P^- b, \end{cases} \\ a \text{ is indifferent to } b (a I^{(1)} b) & \text{iff } a I^+ b \text{ and } a I^- b, \\ a \text{ and } b \text{ are incomparable} (a R b) & \text{otherwise.} \end{cases}$$

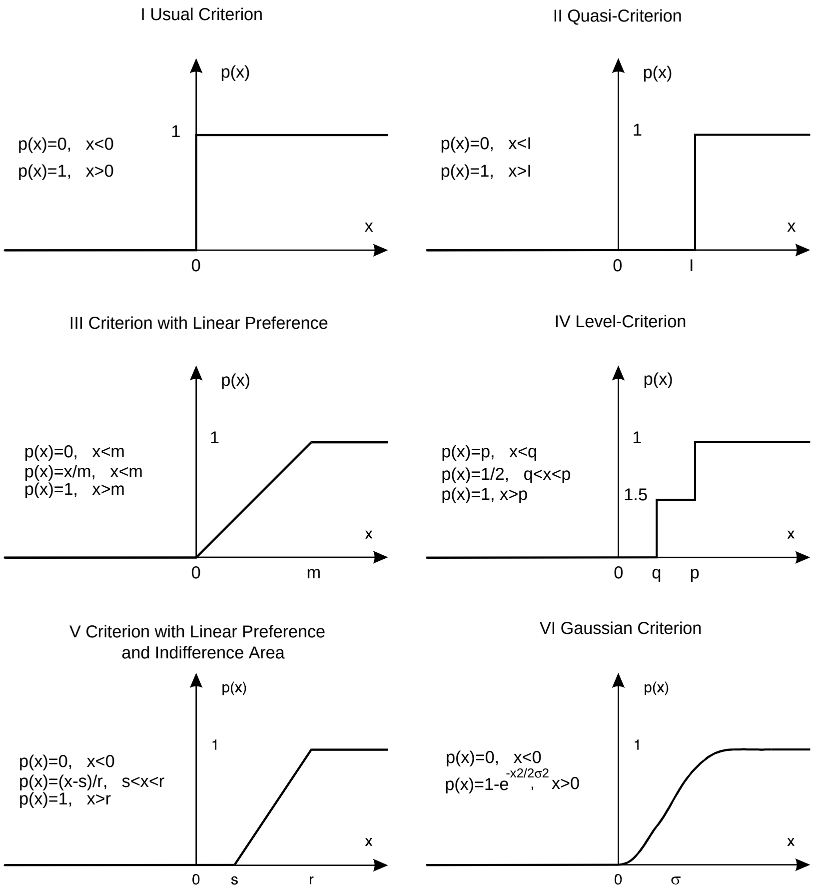


Figure 1 | Preference functions.

The netflow $\phi(a) = \phi^{+}(a) - \phi^{-}(a)$ is used to rank the alternatives by a total preorder $(P^{(2)}, I^{(2)})$:

$$\begin{cases} a \text{ outranks } b (a P^{(2)} b) & \text{iff } \phi(a) > \phi(b), \\ a \text{ is indifferent to } b (a I^{(2)} b) & \text{iff } \phi(a) = \phi(b). \end{cases}$$

Comparison of methodologies

In outranking approaches, the inaccuracy of the data can be modelled through the indifference and preference threshold (so-called pseudocriteria). Of course, the threshold must be assessed for each criterion and for each problem separately.

Comparing the valued outranking relations it could be seen that the netflows are identical between ELECTRE III and PROMETHEE II. Then the ranking of the alternatives by a certain procedure based on these flows must also lead to the same solution.

Basically, these methods differ in their MultiCriteria Aggregation Procedure (MCAP). ELECTRE incorporates in some criteria a *veto threshold* that blocks the outranking relationship between alternatives. Besides, they do not call for transitivity in their preference structures. The veto threshold impedes an outranking relationship between a and b if $g_j(b) - g_j(a) \geq v_j$ even if $g_k(b) \geq p_k$ for any $k \neq j$ where v_j refers to the veto threshold applicable to the criterion j. In other words, if a is considered to be better than b in all criteria but one and if, on that specific criterion j, b is by far better evaluated than a, the huge gap between a and b is that important that it blocks the preference of a over b and makes two alternate alternatives incomparable. Incomparability may occur only with the so-called distillation process, which may be used in the aggregation phase of ELECTRE methods. Thus, no complete ranking of the alternatives is obtained. The incomparability between some alternatives

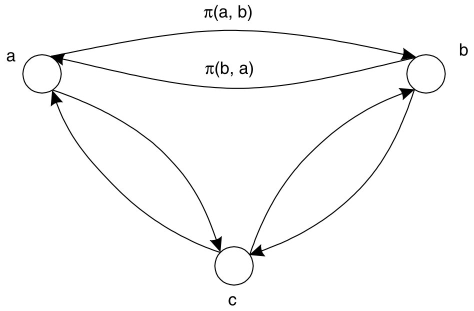


Figure 2 | Valued outranking graph.

can be considered a weakness of the method when it is not able to rank the alternatives completely. Incomparability can also be seen as a way to represent decisions situations where the decision-makers indeed are unable to compare some alternatives. If there is no basis to compare two alternatives reliably, they should be accepted as being incomparable.

To apply the PROMETHEE method, there is no need to define a veto threshold and that makes the procedure of defining parametars simpler and decision-makers can understand the method easier. But in the PROMETHEE method, it is necessary to define the preference function. Talking with decision-makers and being in touch with them all the time a preference function, which will reflect all characteristics of the alternatives, can be choosen. Besides, there are problems in which solving the veto threshold cannot be used and a preference threshold needs to be defined, and in that case the PROMETHEE II method needs to be applied.

The definition of the threshold, however, is not a simple task; the decision-maker's preference discrimination thresholds, when obtained, and also the judgments considering the uncertainty of the data, may be used in defining the thresholds. The definition of the veto thresholds for discordance will be more difficult, since the degree of compensation may be too much for the decision-makers to be defined. Also the difference from ELECTRE III solutions to PROMETHEE II is not very big. Since the 'netflow' of PROMETHEE and ELECTRE III is equal, with the same type of thresholds, the difference is due to the varying procedure used in the construction of (partial) pre-order. However, the possibility to use veto thresholds in ELECTRE III for reducing the compensation between the criteria may result in completely different rankings than the other method.

The choice of the method for multi-criteria decision-making depends on the problem needing to be solved, the decision-makers' familiarity with the MCDM methods and the time they are ready to invest in getting acquainted with the chosen method. The method used has to be easily and quickly understood by the decision-makers who often have a minimal mathematical background and no knowledge about decision analysis. One of the benefits of MCDM methods is that the decision problem immediately becomes clearer after it has been formalized in terms of alternatives and criteria. The MCDM formulation provides a comprehensive framework for storing all relevant problem information and makes the requirements for new information explicit.

Several aggregation methods might also be integrated. For instance, Cost–Benefit Analysis (CBA) could be used for economic indicator assessment and then MCDM used to integrate those with environmental and social indicators. Using the CBA it is important to represent as many relevant effects of a measure as possible. These indicators used in the CBA should be able to be quantified and assessed by monetary units. The result is a multitude of criteria and indicators whose connections are not clarified. Further, the CBA needs a summarizing approach which means a lot of indicators (all possible cost components) covering all quantifiable aspects have to be established. MCDA, on the other hand, forces the users to restrict the number of indicators and to find out the right indicators which explain the system behaviour best. The advantage of this method is that the chosen indicators need not be assessible in monetary terms.

GENERIC FRAMEWORK OF CCR

The generic framework of CCR was developed using WISE (Web-based Intelligent Systems Environment) that could be easily configured for the specific DSS (Simeunovic *et al.*, 2002). WISE represents a set of Java packages with specific organization and usage that could be freely and easily combined into a consistent whole, according to the specific problem at hand.

The following are the three main functional packages of WISE:

- WISE.ES – the package facilitating the development of conventional, rule-based expert systems in the Java language.
- WISE.MCDM – the package facilitating the multi-criteria decision-making process, offering the most widely used methods, PROMETHEE II.
- WISE.FUZZY – the package facilitating fuzzy sets, fuzzy production rules and fuzzy linguistic functions (usually used together with the WISE.ES package).

For the CCR decision support tool, the WISE.MCDM package represents the core module. The WISE.MCDM package facilitates the multi-criteria decision-making process and implements MCDM algorithms of the 'outranking' type PROMETEE II (Salminen *et al.* 1998).

WISE.MCDM PACKAGE ARCHITECTURE

Using WISE packages it is very easy to create the skeleton of every Web-based intelligent decision support tool (Simeunovic *et al.* 2002). Figure 3 shows the core WISE-based DSS architecture used.

A concrete Web-based decision support tool consists of a graphical user interface (GUI), central WISE layer and knowledge and data warehouse (Vranes 2004). The GUI can be realized as a standard Web application which is produced using standard script languages (it is possible to use Java Server Pages and also Active Server Pages technologies with JavaScript and VBScript languages). *Structured query language* (SQL) has been chosen for the CCR decision support tool to support the *relational database management system* (RDBMS).

CCR STRUCTURE

The CCR decision support tool is based solely on the information in the current version of the ICS-UNIDO compendium of wastewater treatment and water purification technologies (Buitrago *et al.* 2002), based on compiling readily available information from the literature or personal communications with the involved technology owners/vendors/inventors. However, it could be easily extended in the future to reflect additional information acquired and/or updates, revisions or additions to the ICS-UNIDO repository of best available technologies.

The CCR decision support tool has been designed and implemented over a multi-criteria analysis system and utilizes a reference database in which groundwater remediation technologies have been grouped in classes and categories according to their type of application (*in situ* and *ex situ*) and to the main mechanism involved in the process (physical, chemical, biological, thermal).

The first prototype of CCR includes 7 groups of established technologies (biological, physico-chemical and thermal), 8 target contaminants and 8 ranked criteria.

The structure of the database and the technologies available in the current stage of the CCR decision support tool are shown in Table 1. The target contaminants and criteria used for the CCR decision support tool implementation are also indicated in Table 1.

For the technology evaluation performed with the CCR decision support tool, some criteria have been selected and a specific rating system has been developed. Each technology has then been rated according to its performance under each criterion.

Not all the stakeholders are equally interested in the criteria listed above. Investors are more interested in capital cost than the environmental acceptability of certain technologies, while the local community and/or the environmentalists

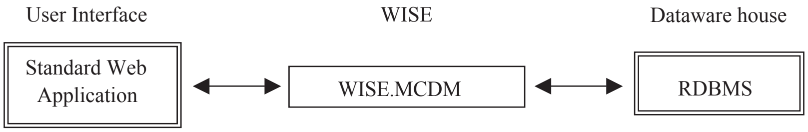


Figure 3 | WISE-based decision support tool architecture.

Table 1 | List of available technologies, target contaminants and criteria used for CCR implementation

Available technologies	Target contaminants	Criteria
• *Ex situ* biological treatments	• Nonhalogenated VOCs (volatile organic compounds)	• Overall cost
• *Ex situ* physical/chemical treatments	• Halogenated VOCs	• Clean-up time
• *Ex situ* thermal treatments	• Nonhalogenated SVOCs (semi-volatile organic compounds)	• Reliability and maintainability
• *In situ* biological treatments	• Halogenated SVOCs	• Availability
• *In situ* physical/chemical treatments	• Fuels	• Capital, operation and maintenance costs
• *In situ* thermal treatments	• Explosives	• Development status
• Containment	• Radionuclides	• Stand-alone character
	• Inorganics	• Residuals produced

have exactly the opposite viewpoint. Therefore, the tool enables its user to select the subset of the criteria offered by the tool to be taken into account in a particular MCDM session, as well as to put the relative weights to the chosen criteria that best reflect their specific preferences.

PROTOTYPE DEMONSTRATION

The software provides a repository of the best available groundwater remediation technologies, a set of indicators for the criteria for evaluating those technologies and default values of weighting factors that could be easily adjusted to suit the user's specific needs and preferences.

Also, it is very easy to add new technology or even a category of technologies, or change the parameters of the existing ones, or introduce new preference functions, etc. CCR is a Web-based application, so that beneficiary' institutions from all over the world could easily access it, once they are properly authenticated.

The software presents its users with a variety of configuration and input parameters from which to choose. Several are mandatory (such as identifying the technologies to be evaluated), but there are many that the user can choose to leave blank or use the supplied default values. This way, the user decides how to tailor the analysis to satisfy his/her specific needs.

Multicriteria analysis of all the factors involved in the decision process determines whether a groundwater remediation strategy is a feasible, effective and efficient solution and whether it satisfies all criteria and constraints defined by the user. Depending on the context in which groundwater remediation technology assessment and selection is performed, the user can tailor the decision strategy, balancing out various effectiveness and efficiency parameters, other criteria and constraints. From the user's point of view, the general algorithm for the CCR decision support tool analysis is described in Figure 4.

The user of the CCR, after inputting data relevant to the project and the general site characteristics (e.g. name of the site, location, geographical coordinates, etc.), then defines the contaminant (or a group of contaminants), uses a full set of technologies or indicates a subset of technologies in which there is interest and ranked criteria and indicates the criteria, preference functions (or use default functions chosen by the CCR developers) and corresponding weighting factors.

After the criteria are selected and their relative preferences set by the user, the multi-criteria decision-

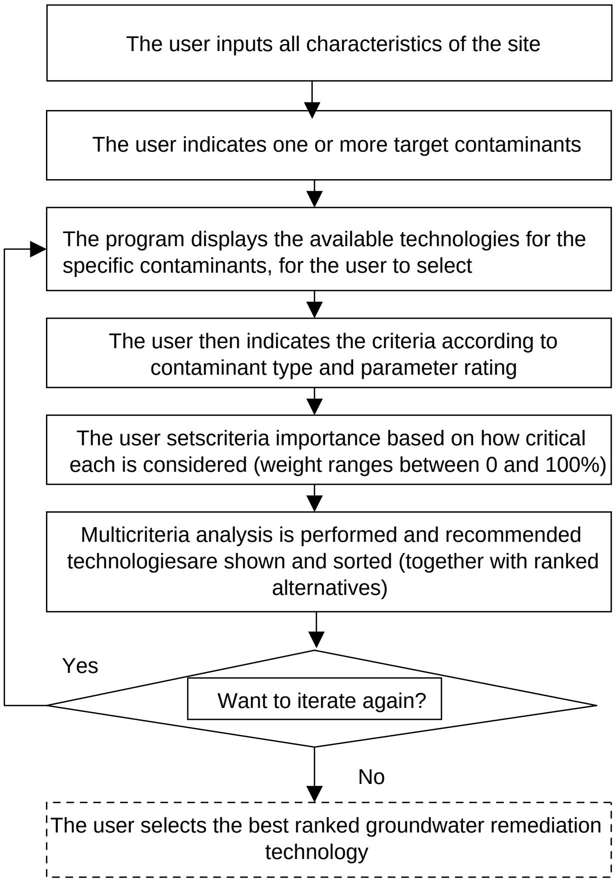


Figure 4 | General algorithm supported with CCR.

making process starts and the system recommendation as well as ranked alternatives are presented to the user.

Figure 5 shows the application's main analysis window, which consists of the current state of the configuration and a few dialogs for data entry purposes for creating a new project. It is connected to the database that contains previously entered information on available technologies and selection criteria; the database should be registered by the user and/or software administrator.

Dialog boxes requesting the user to indicate the target contaminants to be removed and technologies to be simultaneously evaluated and compared are shown in Figures 6 and 7, respectively.

Then the user indicates the criteria for which previously selected technologies will be evaluated (Figure 8).

In the following step, the user sets criteria importance based on how critical each is considered (weight ranges

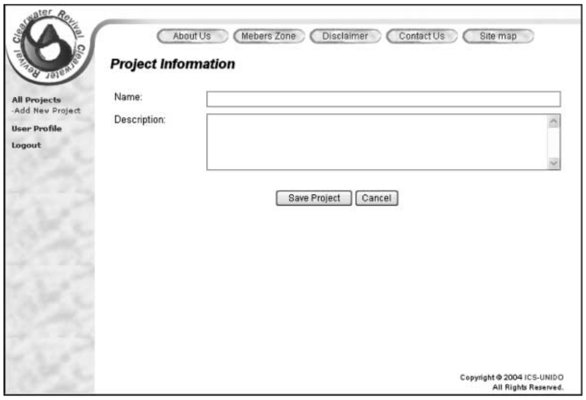
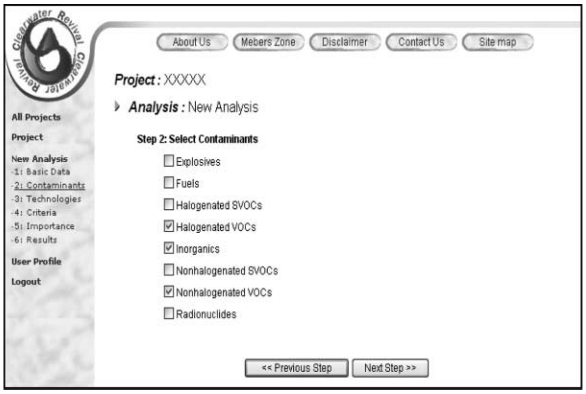


Figure 5 | Main analysis window for the creation of a new groundwater remediation project.

between 0 and 100%). Figure 9 shows the values of all selected criteria for any particular technology. A window 'Multicriteria Analysis Results' (Figure 10) is used for the presentation of the results of the multi-criteria analysis process.

CCR has its limitations (such as being unable to replicate some human decision-making skills; it may not match the decision-making's mode of expression and is constrained by the knowledge it possesses) and could not be used alone to reach an optimum selection. The compromise solution depends strongly on the decision-maker's personality, on the circumstances of the decision aiding process, on the way the problem is presented and on the method that is used (Vincke 1992). It may pose the challenge of integrating CCR with other decision support tools (e.g. decision support tools derived from life cycle analysis or from environmental risk assessment).



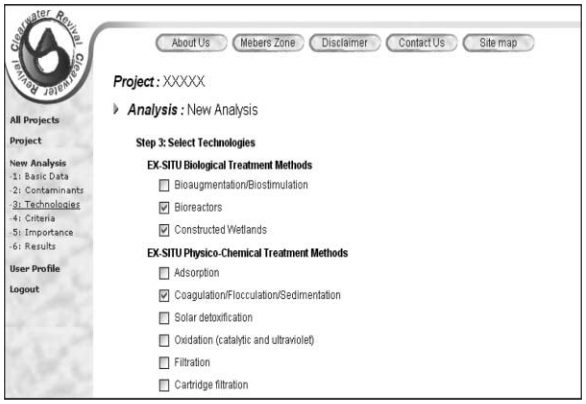
Project: XXXXX

Analysis: New Analysis

Step 2: Select Contaminants

☐ Explosives
☐ Fuels
☐ Halogenated SVOCs
☑ Halogenated VOCs
☑ Inorganics
☐ Nonhalogenated SVOCs
☑ Nonhalogenated VOCs
☐ Radionuclides

Figure 6 | List of target contaminants to be indicated during analysis.



Project : XXXXX

Analysis : New Analysis

Step 3: Select Technologies

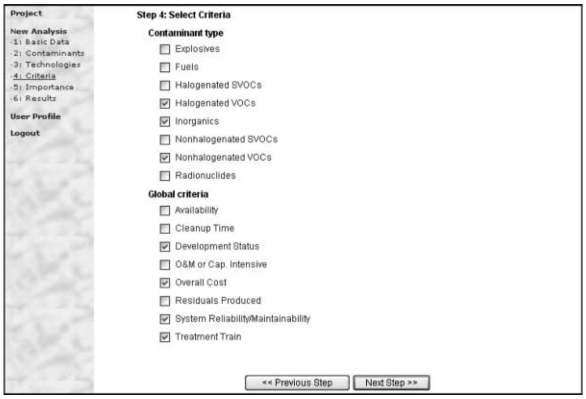
EX-SITU Biological Treatment Methods

☐ Bioaugmentation/Biostimulation
☑ Bioreactors
☑ Constructed Wetlands

EX-SITU Physico-Chemical Treatment Methods

☐ Adsorption
☑ Coagulation/Flocculation/Sedimentation
☐ Solar detoxification
☐ Oxidation (catalytic and ultraviolet)
☐ Filtration
☐ Cartridge filtration

Figure 7 | List of technologies to be evaluated during analysis.



Step 4: Select Criteria

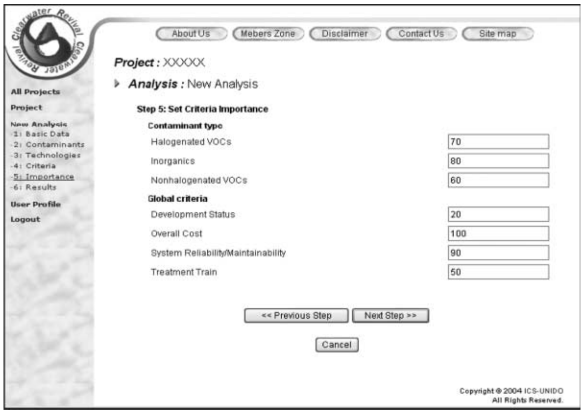
Contaminant type

☐ Explosives
☐ Fuels
☐ Halogenated SVOCs
☑ Halogenated VOCs
☑ Inorganics
☐ Nonhalogenated SVOCs
☑ Nonhalogenated VOCs
☐ Radionuclides

Global criteria

☐ Availability
☐ Cleanup Time
☑ Development Status
☐ O&M or Cap. Intensive
☑ Overall Cost
☐ Residuals Produced
☑ System Reliability/Maintainability
☑ Treatment Train

Figure 8 | List of criteria to be selected according to contaminant type.



Project : XXXXX

Analysis : New Analysis

Step 5: Set Criteria Importance

Contaminant type

Halogenated VOCs	70
Inorganics	80
Nonhalogenated VOCs	60
Global criteria	
Development Status	20
Overall Cost	100
System Reliability/Maintainability	90
Treatment Train	50

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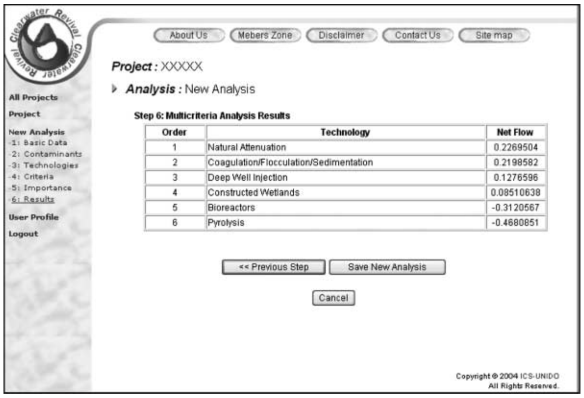
Figure 9 | Set of criteria importance.



Project : XXXXX

Analysis : New Analysis

Step 6: Multicriteria Analysis Results

Order	Technology	Net Flow
1	Natural Attenuation	0.2269504
2	Coagulation/Flocculation/Sedimentation	0.2198582
3	Deep Well Injection	0.1276596
4	Constructed Wetlands	0.08510638
5	Bioreactors	-0.3120567
6	Pyrolysis	-0.4680851

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Figure 10 | Multi-criteria analysis results.

As Guariso & Werthner (1994) already pointed out, the environmental decision support system will not and cannot do the work that remains to be done by humans. Better computer support does not automatically imply a better decision. It is still the human's responsibility to be aware of the environmental situation of the planet and to cope with all the problems connected with it.

CONCLUSIONS

The CCR decision support tool for groundwater remediation technology assessment and selection has been developed in ICS-UNIDO to help beneficiary institutions in this sensitive decision-making process. It is a Web-based decision support tool that allows assessment of the available groundwater remediation technologies against various technical, environmental, financial and social criteria, and selecting the most suitable technology according to the specific objectives and preferences of a particular user/-stakeholder. The demonstration prototype has currently being completed and is the subject of internal validation by means of test runs utilizing data gathered from assessed full-sale applications and verification processes before being posted on the Web for wider testing by beneficiary institutions and/or individuals. Further work is being undertaken to split the list of contaminants and criteria to extend the use of CCR in order to evaluate wastewater treatment and water purification technologies.

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