Development of quality objectives for contaminated sites: state of the art and new perspectives

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Abstract: Local soil contamination, mainly associated with industrial facilities (both in operation and after closure), uncontrolled (industrial and/or municipal) waste landfills, mining and diffused leaching underground storage tanks and pipelines, is an actual and relevant environmental priority in Europe. Different approaches have been applied in the European countries during the past few years to develop the quality objectives for contaminated sites according to the following three categories: the *limit value criterion* for soil and groundwater; the *absolute risk analysis* for a given contaminated site; and the *comparative (or relative) risk analysis* among different potentially contaminated sites. The present paper gives, together with a synthetic state of the art of the contaminated site management situation at different EU countries, a view on the current experience, problems and regulatory requirements in Italy on these possible soil and groundwater quality approaches, also with comparative considerations to other significant European and international strategies.

Keywords: absolute and relative risk assessment; contaminated site; European strategies; health and ecological risk; limit value; quality criteria.

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1 Introduction

Contaminated sites represent a major challenge in many European countries. Local soil contamination, mainly associated with industrial facilities (both in operation and after closure), uncontrolled (industrial and/or municipal) waste landfills, mining and diffused leaching underground storage tanks and pipelines, is an actual and relevant environmental priority in Europe. The occurrence of inorganic and/or organic pollutants in soil, subsoil, sediments and groundwater above certain acceptable levels has negative consequences for all types of ecosystems and natural resources, and subsequently for human health.

The current and the future importance given to soil (and groundwater related) local pollution issue at the European Union level are clearly shown by the 6th Environment Action Programme (expressly asking for a European thematic strategy on soil: EU

Commission, 2001) and the Soil Protection Communication of the European Commission (EU Commission, 2002).

Within an integrated approach for contaminated site identification, characterisation and remediation, an indispensable and initial step certainly deals with the application of reliable and scientifically sound soil and groundwater quality criteria. This application is of strategic importance to define the following goals (de Fraja Frangipane, Andreottola and Tatàno, 1998; D'Aprile and Tatàno, 2005):

1 the effective level of contamination ('how dirty is dirty') for each suspected site;
2 the residual pollutant concentrations after remediation intervention ('how clean is clean') in case of unacceptable level of contamination;
3 finally, a necessary priority list for further interventions (specific investigations, feasibility studies, remediation programme) within the whole number of identified sites at a given territorial area (provincial, regional or national).

In the past few years, different approaches have been developed and applied in the European countries – as well as at the international level – in order to answer to the above-mentioned requirements, according to the following three categories (Andreottola and Tatàno, 1994, 1995):

1 the *limit value criterion* for soil and groundwater;
2 the *absolute risk analysis* for a given contaminated site;
3 the *comparative (or relative) risk analysis* among the different sites, which are potentially contaminated.

The present paper gives, together with a short summary of the contaminated site management situation at some EU countries, a synthetic view on the past and current experience, problems and regulatory requirements in Italy on these possible soil and groundwater quality approaches, also with comparative considerations to other significant European and international strategies.

2 State-of-the-art on the management of contaminated sites at EU level

In the following subsections, a synthetic overview on contaminated sites management in selected European countries is presented, especially focusing on site investigation and classification (directly and expressly summarised from European Environmental Agency (EEA), 2000).

2.1 Austria

Austria started to develop a national policy for contaminated sites in the late 1980s. In 1989, a national remediation programme was introduced and the Federal Act on the cleaning up of contaminated sites was promulgated. The Ministry of the Environment, Youth and Family coordinates the activities related to the Federal Clean-Up Act and is responsible for the allocation of funds for remedial actions. The Federal Environmental Agency is responsible for the central control, maintenance of the contaminated sites register and the assignment of priorities to sites, which are supposed to be funded.

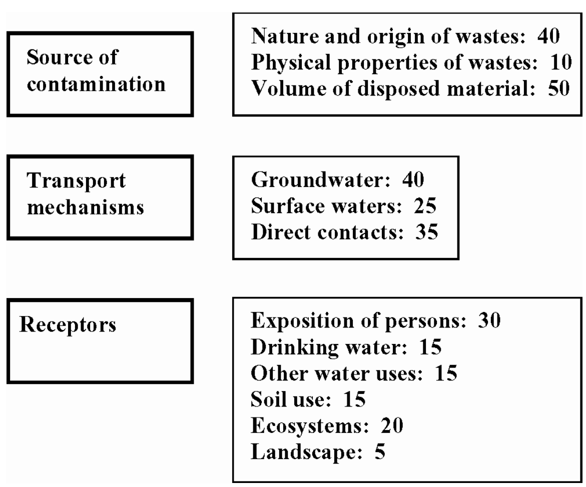
Potentially contaminated sites require a minimum investigation to have a risk category assigned and the sites with a high-risk category have priority for further investigations. The potentially contaminated sites, after a detailed investigation and risk assessment, are included in the inventory of contaminated sites. The polluter-pays principle is applied as far as possible. When the liable party is not able to cover clean-up costs, public funding (retrieved from taxes) is required.

2.2 Belgium

The need for a comprehensive soil protection and remediation policy in Belgium started in the beginning of 1990s. The Kingdom of Belgium has an articulated federal structure, and the three Federal States (Walloon, Flemish and Brussels region) have different legislations concerning contaminated sites. The Flemish region has two main acts (issued in 1995 and 1996) regulating the soil remediation activities: soil standards and background values are established and a register of polluted sites is maintained. In the Walloon and Brussels region, the contaminated site regulation is instead more recent. In the Walloon region, a score criterion for the evaluation of contaminated sites has been properly developed (Figure 1); sources of contamination, transport mechanisms and receptors are assigned with points and two final scores are calculated (risk level, quality of information). The two scores obtained are used to classify the site, according to the following five categories:

- Measures are necessary.
- Periodical monitoring is necessary, which makes measures are possible.
- Measures are not necessary but observation on a regular basis is required.
- The site does not need any further measures.
- More information is needed to assign a category.

Figure 1 Scores for the classification of contaminated sites in the Walloon Region (Belgium) (EEA, 2000)



2.3 Denmark

In Denmark, systematic characterisation of contaminated sites started in 1982, and methodologies for both the site investigation and risk assessment are highly developed. Major legislation addressing contaminated sites in Denmark is the Soil Contamination Act, enforced in 2000. Regional authorities (14 counties and two municipalities) are responsible for registration and investigation of contaminated sites. The National Environment Protection Agency provides guidance to regional and local authorities and supports R&D activities. In those sites where contamination is likely to have harmful impacts on human health, remediation will usually take place only if the soil quality criteria are exceeded ten times corresponding to the level of the so-called cut-off value. In the preliminary study of potential contaminated sites, a preliminary risk assessment is carried out: if the site, as a result of the preliminary survey, is mapped at level 1, a preliminary investigation will be carried out. Guideline values for soil (based on the most sensitive land use) and groundwater (based on drinking water values) are applied as orientation values. In addition, a site-specific risk assessment will be conducted to assess the probability of leaching of contaminants to the groundwater, since soil guideline values do not take into account such effects. Sites that are considered to pose a risk for the present land use or for drinking water resources have the highest priority and will be taken into the next step of the process (that is, the main site investigation).

2.4 France

According to EEA, 2000, France has no specific legislation concerning contaminated sites: national policy and national measures to be applied are defined in circulars of the Minister of the Environment to the Heads of the French Departments. A key document is the circular letter of the Minister of the Environment from 3 December 1996, defining major features of a national policy towards contaminated sites. At the central level, the section in charge for the contaminated site management is the Direction de la Prévention des Pollutions et des Risques (DPPR) of the Ministry of National Land Planning and the Environment; at the local level, the basic geographical administrative unit is the Department (99 in total).

In the preliminary survey, an initial site characterisation and a Simplified Risk Assessment (SRA) are developed with an aim to identify potentially contamination sources and to briefly evaluate its potential impacts on human health and the environment. Guideline values (for water and soils) called as 'Valeurs de Constat d'Impact (VCI)' are defined, according to media uses. Following the results of the SRA, the site is classified in any one of the three following groups:

1. sites needing further investigation and detailed risk assessment
2. sites for which monitoring should be applied
3. sites that can be used for specific purposes without any further investigations or measures.

The results of the preliminary investigation define the need for conducting a detailed risk assessment, which is supposed to evaluate the impact on human beings and the environment and the need for remedial actions to reduce or eliminate these risks.

2.5 Germany

In Germany, each of the 13 Federal States and three Free Trading Cities has developed its own strategy towards the contaminated site problems, including individual registration systems, evaluation systems, prioritisation procedures and risk assessment methodologies. According to the German Constitution, the Federal States are responsible for registration, inventory, risk assessment and remediation of contaminated sites. The polluter-pays principle is applied. Although the individual contaminated soil management approaches vary in detail depending on the administrative structures and responsibilities in each Federal State, the general procedure is very similar and can be characterised with the following steps:

1 identification and registration

2 investigation and risk assessment

3 remediation and/or monitoring.

2.6 The Netherlands

In 1976, the Dutch Government decided to include soil protection in the national environment policy. Concerning technical-scientific guidance on soil pollution, the widely known ‘Dutch list’ of limit values has been developed in the 1980s and followed by many European countries adopting the ‘limit value criterion’ (Section 3). The Dutch list has been completely reviewed in 1994 along with the amendment of the Soil Protection Act. Apart from national legislation, voluntary agreements between industry and public authorities came into being. Regulatory responsibilities are divided among the Central Government, the 12 Provinces (plus larger cities) and the local authorities. The Dutch approach of site identification and investigation consists of the following steps:

1 the preliminary survey (to substantiate the suspect of serious contamination)

2 the preliminary investigation (to prove contamination)

3 the main investigation (to assess the urgency and type of remediation).

There are three major soil quality objectives (‘target values’, ‘limit values’ and ‘intervention values’) of which each one can be defined for the soil, water and air environmental sectors. The strategic goal of soil remediation in the Netherlands is to reach the ‘target values’, representing multifunctional soil quality.

2.7 Sweden

In 1995, a new approach towards contaminated sites was proposed; the Swedish Environmental Protection Agency issued a remediation action plan with the objective to comprehensively identify and investigate the national contaminated sites and carry out remediation where necessary. The Swedish Environmental Protection Agency is responsible for the central coordination, the overall planning, the prioritisation and the allocation of general funds for investigations, inventories and remediation of contaminated sites. As the first step after the site identification, a risk classification is carried out based on the available information that can be collected from public and private archives, also including both geological and geochemical maps. The risk classification is an evaluation of the toxicity of contaminants, their concentrations, the potential for further migration to the surroundings and the sensitivity and the protective value of the surroundings, based on the following classes:

- risk class 1: very high risk
- risk class 2: high risk
- risk class 3: moderate risk
- risk class 4: low risk.

Only those sites classified in classes 1, 2 and 3 would be continued in the investigation process (that is, the main site investigation).

2.8 United Kingdom

In UK, legislation concerning contaminated sites was addressed in the Environment Act (1990), amended in 1995 and enforced in 1996. In general, a two-step assessment approach is used for assessing the impact of contamination on groundwater and surface water:

1 *A qualitative assessment* to determine whether the contamination at a site has the potential for polluting either the ground or surface water (this step requires a desk study and a site visit, both specially designed as part of this process).

2 *A quantitative assessment*, including modelling techniques where appropriate, to establish the extent and severity of any contamination that may be present (this step requires a detailed and specially designed site investigation).

The likelihood of the presence of contaminants, the potential migration pathways and the potential risk to man and the environment are assessed and grouped into one out of four priority categories. If possible, it is assessed whether the contamination exceeds guideline values.

2.9 Switzerland

First, attempts towards both the assessment and remediation of contaminated sites in Switzerland were made by the local authorities in the year 1985. In 1991 the Federal Government started to develop a national policy for contaminated site management, and in 1994 the first concept was published. In 1995 the legislation on environmental protection was revised and the major objectives of the concept were integrated in the relevant contaminated site management part. The Swiss approach to contaminated sites is based on the following principles. The main goal is to stop pollution sources that lead to, or have the potential to result in, hazardous and therefore unacceptable emissions in a legally protected medium, such as groundwater, surface water, soil, air and humans. For the quantification of the site hazard (potential), according to the 'limit value criterion' (Section 3), a set of intervention values for an aqueous phase and for a gaseous phase have been defined. In most cases, the numerical values correspond to drinking water values. Otherwise, the values have been toxicologically derived from the unit risk approach according to the U.S.EPA (United States Environmental Protection Agency).

The underlying assumption is that the leachate or pore water infiltrating into groundwater should not exceed drinking water limit values for any individual compound. If a site is classified as 'contaminated' based on the initial field investigation, the further actions required are a detailed site investigation, risk assessment and possibly a feasibility study for remedial options. Based on these investigations, the urgency and extent of remedial measures are defined for achieving a long-term and sustainable solution.

3 The 'limit value criterion': principles and Italian approach

The *limit value criterion* consists in the determination, according to different methodologies, of 'limit values' for contaminant concentrations in soil and groundwater, to be compared with the effective values detected at the suspected site, in order to define the contamination level and, eventually, the goal for the remedial action. This approach is commonly used for other environmental media (air and surface water). It has the clear advantage of simplicity and immediate applicability; the judge, the site's owner, the operator of the remedial action clearly know their own liabilities and tasks. On the other hand, the limit value approach gives rise to some relevant questions (Andreottola and Tatàno, 1994, 1995; de Fraja Frangipane, Andreottola and Tatàno, 1998): is it in fact, correct to establish a unique and invariable value as a definitive distinction between the 'good' or 'poor' quality of a soil or groundwater, independently from the site-specific conditions, potentially exposed targets and related true risk levels?

The different limit value lists for soil and groundwater quality, proposed in the last decade at international and European level, can be classified according to two characterising features (Andreottola and Tatàno, 1994, 1995; de Fraja Frangipane, Andreottola and Tatàno, 1998; D'Aprile and Tatàno, 2005):

1 Limit concentrations either differentiated according to the present or future site use (i.e. agricultural, commercial/industrial, residential/recreational, green areas: so called *land-use dependent criteria*) or univocal and therefore not influenced by the land use (so called *land-use independent criteria*).

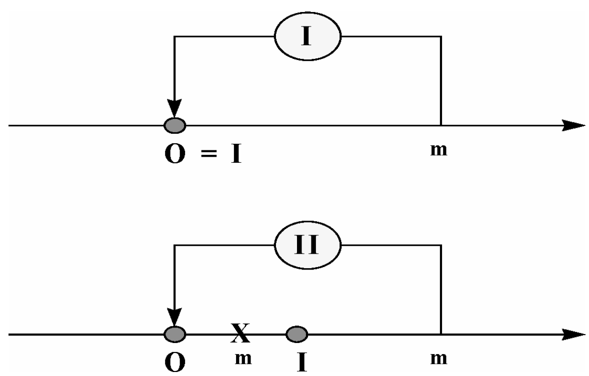
2 Criteria identifiable in one of the approaches of Figure 2 (Visser, 1993): – *approach II* (also called *two levels approach*): the *limit concentration I*, which indicates, when overcome, the need for a remedial intervention, is distinguished by the other *limit concentration O*, lower than I, which represents instead the remediation objective; – *approach I* (also called *one level approach*): the limit concentrations I and O, as previously defined, are now coincident.

For instance, the above-mentioned 'Dutch List' (Subsection 2.6) can be classified as a land use independent, multi-functional list belonging to the 'II levels approach'.

As far as the current Italian situation is concerned, recently the national regulation on contaminated sites has been changed (D'Aprile, Baciocchi and Berardi, 2006) and the original 'limit value' approach has been included into a 'risk-based' multi-tier one. The old national technical-scientific regulation on contaminated soil management (so called 'D.M. No. 471/1999' Decree: Italian Ministry of Environment, 1999) introduced in fact an official soil and groundwater quality criterion for contaminated sites, consisting of the following lists:

- A soil and subsoil list belonging to the 'I level approach' of Figure 2, for no. 94 organic and inorganic contaminants and with limit values (as mg kg DM^{-1}) differentiated for residential/recreational and commercial/industrial land uses.
- A groundwater list also belonging to the 'I level approach' of Figure 2, for no. 92 organic and inorganic contaminants but with water-use-independent values (as μg l^{-1}).

Figure 2 'Limit value criterion' approaches (Visser, 1993; de Fraja Frangipane, Andreottola and Tatàno, 1998; D'Aprile and Tatàno, 2005). Legend: O = remediation objective; I = intervention level; m = contaminant concentration measured at the site; I = 'one level' approach; II = 'two levels' approach



As an appropriate scientific approach for contaminated sites, at different European countries the limit value lists for soil and groundwater are currently being derived often as risk-based generic values according the application, under reasonable maximum exposure conditions, of a given protocol for absolute, sanitary risk assessment (Section 4). The new Italian regulation on contaminated sites (as a part of the so called 'Legislative Decree No. 152/2006') reflects (expressly at its Section IV, Title V) this approach, requiring the application of a 'Tier 2' absolute sanitary risk assessment to calculate site-specific target levels (expressly called 'CSR' – risk threshold values), while the 'limit values' of the above-mentioned 'D.M. No. 471/1999' (indeed with some changes) are used as 'Tier 1' screening values (expressly called 'CSC' – contamination threshold values), even if it was clearly demonstrated that they are not properly risk-based.

4 The 'absolute risk analysis': principles and international standards

The *absolute risk analysis* can be defined as a scientific and systematic methodology for the evaluation of the contamination level of the environmental media at a given suspected site, in terms of quantification of the associated risk for human and ecological targets. If the main goal of the application of the absolute risk analysis is the quantification of the risks associated with the exposition pathways actually or potentially active for human targets, the commonly used term is *health-sanitary risk analysis*. Otherwise, if the application of the risk analysis procedure has the aim of evaluating the exposure for ecological targets (terrestrial and/or aquatic animals, birds, etc.), the used denomination is *ecological risk analysis*. The first international attempt of standardisation of the absolute risk analysis methodology was done about 10 years ago when, in the USA, national programmes for the management of petroleum underground storage tanks (so-called ‘Underground Storage Tank, UST’ programme) and contaminated large sites problems (so-called ‘Superfund’ programme) were developed. The 1995 ASTM E 1739–95 (American Society for Testing and Materials) standard applies the so-called ‘RBCA, Risk-Based Corrective Action’ procedure at petroleum release sites (ASTM, 1995). Its subsequent development (ASTM E 2081–00 standard) extends the application of ‘RBCA’ methodology to all the chemical release sites (ASTM, 2004). The U.S.EPA fundamental documents on ‘RAGS, Risk Assessment Guidance for Superfund’ (U.S.EPA, 1989, 1991) and mainly ‘SSLs, Soil Screening Levels’ (also in temporal evolution: U.S.EPA, 1996a,b, 2002) represent the international qualified starting point for the technical guidelines on absolute risk assessment developed by the local authorities. Among the standardisation attempts, the Italian UNICHIM (2002) and the CONCAWE (1997) technical-scientific guidelines are also worth mentioning.

5 The ‘absolute risk analysis’: the Italian situation (present regulation and new perspectives)

5.1 The application of sanitary absolute risk analysis at Italian National Priority List sites

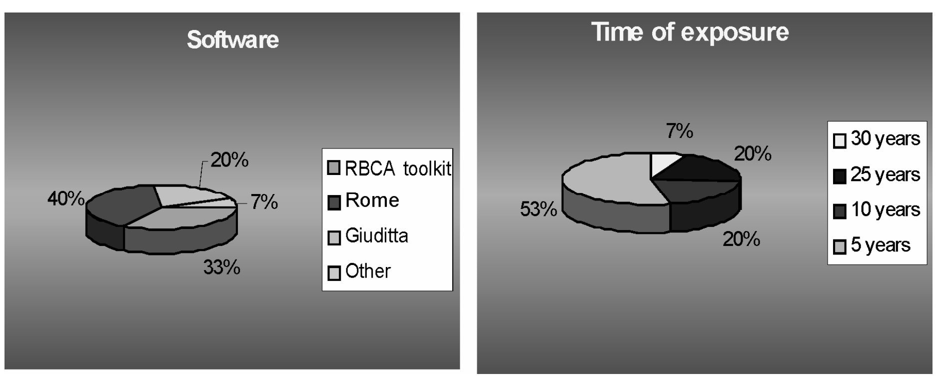
The application of sanitary absolute risk analysis at ‘National Priority List (NPL)’ sites is regulated in Italy by the above-mentioned ‘D.M. No. 471/1999’ Decree (Section 3). This decree states in fact that the sanitary absolute risk analysis can be applied only *if the preliminary remediation project shows that the established chemical quality levels* (according to the above-mentioned official soil and groundwater quality lists: Section 3) *cannot be reached, even by the application of the best available remedial technologies at sustainable costs.* In such a condition, the legislation, therefore, enforces the authorisation of remediation actions with so-called ‘security measures’: specifically, the residual chemical concentration values, above the soil and groundwater limits established by the ‘D.M. No. 471/1999’ Decree, are then just determined by the application of the absolute risk analysis. This approach does not include, however, the preliminary calculation of generic risk-based screening levels for soil and groundwater, which are instead univocally already established by the ‘D.M. No. 471/1999’ (with the above-mentioned official quality lists: Section 3), and then only allows the application of the risk assessment procedure starting from the internationally called ‘site-specific, II level’ (U.S.EPA, 1996a,b). Hence the use of the absolute risk analysis is permitted in the preliminary remediation project when the results of the main characterisation are available. Due to this fact and since the identification of the exact perimeter of many Italian NPL sites is rather recent, the remediation activities at these sites primarily focused on the main characterisation and emergency measures for groundwater (in most cases heavily contaminated).

The great part of remediation projects containing sanitary absolute risk analysis applied to sites included in the perimeter of Italian NPL areas was presented during 2003–2004. The only exception is the sanitary absolute risk analysis presented, together with the final remediation project, for the Naples-Bagnoli site (Campania Region) (Decree of the Italian Ministry of the Environment, July 28 2003). The sanitary absolute risk analysis for the Naples-Bagnoli site was developed in 2001–2002 for the determination of the residual concentrations of heavy metals, in the main characterisation phase, which resulted above the quality limits established by the 'D.M. No. 471/1999' Decree (indeed corrected according with the site-specific background values). The risk-based values were calculated by the 'GIUDITTA vs. 1.2.' software (developed by the Province of Milan: Subsection 5.2) and the exposition parameters were imposed by the Italian Ministry of the Environment.

5.2 The Porto Marghera-Venice Lagoon area case study and synthetic description of some used software tools

During the evaluation of the sanitary absolute risk analysis projects presented in 2003–2004, the Environmental Control Authorities, both national (Italian Ministry of the Environment, APAT – Italian Environmental Protection Agency and Technical Services, and ISS – Italian Health Research Institute) and local (Regional Environmental Protection Agencies, Regions, Provinces and Municipalities), verified significant differences in procedures, models and input parameters used in the calculation of the sanitary absolute risk. A relevant example of these differences is given in Figure 3 concerning the large Venice-Porto Marghera National Priority List (NPL) area (northeastern Italy). At this case study contaminated area, the software tools used for conducting the absolute risk analysis were: the 'RBCA Tool Kit for Chemical Releases' (GSI, 1998), the above-mentioned 'GIUDITTA' (Province of Milan, 2003), another Italian available model called 'ROME' (ANPA, 2002) and others.

Figure 3 Example of the differences in software tools (*left*) and time of exposure for carcinogenic substances (*right*) used at different industrial properties within the Porto Marghera-Venice Lagoon NPL area for the application of human-health absolute risk analysis. These differences led to strong disagreements in the evaluation of human health risk



All these software tools generally follow the approach of the ASTM–RBCA procedure (Section 4), with some differences in the implementation that are discussed and compared in detail in (APAT, 2005).

Briefly, the *RBCA Tool Kit for Chemical Releases* is a commercial software based on Microsoft Excel® spreadsheet format (GSI, 1998). This software is a comprehensive modelling and risk characterisation package for ‘Tier 1’ and ‘Tier 2’ ASTM-RBCA evaluations for chemical release sites. The ‘RBCA Tool Kit’ combines contaminant transport models and risk assessment procedures to calculate the baseline risk levels (so-called ‘direct’ or ‘forward’ assessment mode: UNICHIM, 2002) and derive risk-based clean-up standards (so-called ‘inverse’ or ‘backward’ assessment mode: UNICHIM, 2002) for a full array of soil, groundwater, surface water and air exposure pathways. The ‘RBCA Tool Kit’ includes fate and transport models for all exposure pathways, capable of addressing a wide array of chemicals, including petroleum fuels and chlorinated solvents. Multiple points of exposure can also be evaluated in the same simulation. A wide range of default transport parameters is provided for various soil types and its characteristics. In addition to steady-state air, soil and groundwater exposure models, the ‘RBCA Tool Kit’ can also be used to conduct transient groundwater modelling analyses to assist in estimating not only the range of contaminant concentrations that might occur at an exposure point but also how soon the exposure could occur. The ‘RBCA Tool Kit’ includes an extensive chemical database covering a wide array of chemicals, including organic solvents, petroleum hydrocarbons (differentiated in ‘Total Petroleum Hydrocarbon’ (TPH) fractions), pesticides, metals and more. After the user has identified the chemical(s) of concern, the necessary chemical properties are loaded automatically from the database. The database can be expanded and customised by the user for state-specific values.

GIUDITTA and *ROME* are instead two Italian public-domain software tools developed, respectively, by the Province of Milan (Province of Milan, 2003) and the Italian Environmental Protection Agency (ANPA, now APAT: ANPA, 2002) for the application of human-health risk assessment at contaminated sites according to the Italian regulation. The analytical equations implemented in the ‘GIUDITTA’ and ‘ROME’ software tools are mainly taken from the ASTM-RBCA standard, while for the default exposure parameters U.S.EPA guidelines and documents are also taken into account (Section 4). The ‘GIUDITTA’ software has been recently (June 2006) updated following the indication of the technical procedure issued by APAT (Subsection 5.3) and according to the new regulation on contaminated sites (‘Legislative Decree No. 152/2006’: Section 3). More information on the updated version of these two Italian public-domain software tools can be usefully found at the related web sites, where links for the free download are available at: www.provincia.milano.it (Province of Milan), www.apat.it (APAT).

Expressly regarding the application of the above synthetically described and other software tools to Porto Marghera-Venice Lagoon NPL area, the differences in the implemented equations and in the exposure parameters (especially, the time of exposure for the carcinogenic substances) used to calculate the risk led, in many cases, to important differences in the results of the risk analysis, due to two main reasons:

1 Some of the software tools use different equations derived from different procedures for the same exposure pathways (Pieroni and Mariotti, 2003).

2 The time of exposure is proportional to the risk, according to the following equations:

$$\mathrm{HQ} = C \times \frac{E}{\mathrm{RfD}}$$ (‘Hazard quotient’, for non-carcinogenic substances)

$R = C \times E \times \mathrm{SF}$ ('Individual excess cancer risk', for carcinogenic substances)

where C = contaminant concentration at point of exposure; RfD = reference dose (mg kg^{-1} day^{-1}); SF = slope factor (mg^{-1} kg day); E = exposure rate (directly proportional to time of exposure).

The above-mentioned synthetic considerations confirm the necessity for a standardisation of the procedures and input parameters used in the application of the absolute risk analysis to limit the 'subjectivity' in choosing of important parameters that could influence the final results, in terms of protection for the human health and the environment.

In the attempt to give an emergency response to the Italian Ministry of the Environment for the evaluation of the risk analysis presented for the Venice-Porto Marghera NPL area, APAT, ISS and the Veneto Region Environmental Agency (ARPAV) produced a common technical document containing a proposal of criteria for the evaluation of sanitary absolute risk analysis at Porto Marghera area (APAT, 2004). The last version of this document (22 July 2004) was approved by the Italian Ministry of the Environment on 6 August 2004 and gives preliminary indications on the calculation of the source representative concentration, on the exposure parameters and on the evaluation of indoor/outdoor inhalation pathways.

5.3 The Italian Environmental Protection Agency (APAT) standard

The above-mentioned criteria for absolute risk analysis have been widely discussed inside the technical procedure developed by a specific Italian work group instituted (2004) and coordinated by APAT. The resulting Italian technical procedure titled 'Methodological criteria for the application of absolute risk analysis at contaminated sites' (APAT, 2005) contains important indications on the following points:

- *Source of contamination:* representative concentration and geometrical parameters.
- *Exposure pathways*: transport factors, sensitivity analysis for site-specific parameters.
- *Final receptors*: exposure scenarios/parameters, risk calculation and acceptable risk values (for carcinogenic and non-carcinogenic effects).

A database of the chemical, physical and toxicological characteristics of over 100 substances, developed by ISS in cooperation with the Italian National Institute for Worker Safety (ISPESL), constitutes one of the appendices of the above-mentioned document. Other relevant appendices deal with the application of statistical Monte Carlo analysis (for probabilistic approach), the benchmarking of commercial and public-domain software tools, the problem and modelling for potential Non-Aqueous Phase Liquid (NAPL) occurrence.

An update of the above-mentioned APAT standard, which was revised and improved in order to be applied also for the calculation of site-specific target levels, is available on the APAT web site (www.apat.it) starting from the end of July 2006.

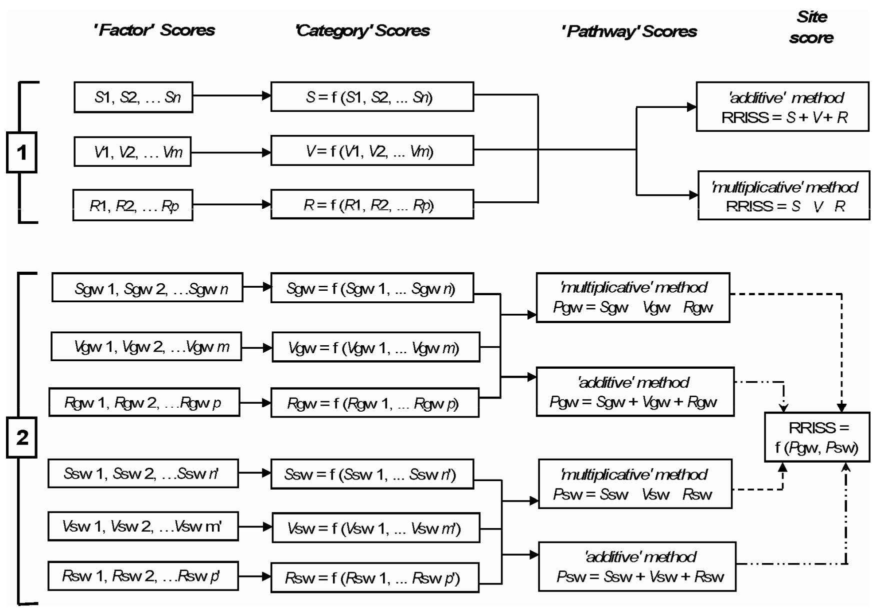
6 The 'comparative risk analysis': principles and international standards

This category of risk analysis criteria includes all those score ranking procedures that provide, through the experimental data sampled during site inspections and all the collected available documentation on the whole amount of potentially contaminated sites, an evaluation of the hazard posed by each site *in comparison* to the others (Andreottola and Tatàno, 1994, 1995; de Fraja Frangipane, Andreottola and Tatàno, 1994, 1998). Therefore, an evaluation of the 'relative' risk is given, with the consequent possibility of establishing a 'priority list' of the sites, which require further actions. This priority list can play a major role for site remediation planning and financing, as the suspected sites can be even more thousands, while the available remediation budget (at municipal, provincial, regional or national level) is limited in most cases. As a consequence, the application of *comparative* (or *relative*) *risk analysis criteria* allows to restrict the whole amount of suspected sites to a subset, on which further more detailed inspections, absolute risk analysis and eventually clean-up actions will be carried out (Andreottola and Tatàno, 1994, 1995; de Fraja Frangipane, Andreottola and Tatàno, 1994, 1998). A common problem arising in the development of a comparative risk criterion is the choice of the numerical values to be attributed to each parameter, because of its inevitable subjectivity: anyway, even if some limitation exists (arbitrariness in parameter estimation, effective availability of field data required for the criterion application), comparative risk criteria are a very important tool to avoid that the contaminated site management is being carried out mainly (or only) under the outcry of the soil contamination events, the public opinion pressure, political influences and market perspectives (Andreottola and Tatàno, 1994, 1995; de Fraja Frangipane, Andreottola and Tatàno, 1994, 1998).

As far as the calculation procedures of comparative risk analysis is concerned (at least for the predominant Italian situation: Figure 4), normally some *Factor Categories* (as for instance: *S – source* of contamination, *V – vehicles* of contamination and *R – receptors*) are considered (either differentiated or not for specific migration pathways, as for instance *gw – groundwater, sw – surface water, a – air* and *dc – direct contact* with soil): each category then includes a group of *Factors* (or *Parameters*), whose scores, assigned to the investigated site and mathematically related among them (according to a given *function – f*), identify the *Category Score*. The Category Scores are finally related among them (normally according to either a 'multiplicative' or 'additive' method), to obtain the *Pathway Scores* (eventually) and finally the *Site Score* (or properly definable *Relative Risk Index Site Score - RRISS*). It should be pointed out that the selection of a multiplicative method for the Pathway Score determination generally implies that a migration pathway has to be fully affected by the contamination, in order to give a related score different from zero (Andreottola and Tatàno, 1993a). In order to make the formation of a priority list possible, most of the comparative risk criteria provides for the normalisation of the resulting Relative Risk Index Site Scores (RRISS) to the convenient numerical scale of 0–100.

The U.S.EPA standard 'Hazard Ranking System (HRS)' (either according to the original 1982 or the updated 1990 version: U.S.EPA, 1984, 1990) and the Canadian 'National Classification System (NCS)' (CCME, 1992) have been assumed worldwide as a possible starting point for deriving regional and/or national comparative risk assessment approaches.

Figure 4 Possible calculation approaches for Italian comparative risk analysis criteria. Legend: 1 = schematisation model approach without migration pathways; 2 = schematisation model approach with two migration pathways; *S* = contamination source (with no. *n*, *n*' factors); *V* = contaminant vehicles (with no. *m*, *m*' factors); *R* = final receptors (with no. *p*, *p*' factors); gw = groundwater pathway; sw = surface water pathway; RRISS = relative risk index site score



Source: de Fraja Frangipane, Andreottola and Tatàno, 1994.

7 The ‘comparative risk analysis’: the Italian situation and perspective

According to the legislative requirements for expressly defining regional priority lists of contaminated sites to be reclaimed within the Regional Clean-up Plans (as previously requested by the specific ‘Decree No. 16/5/1989’ of the Italian Ministry of the Environment and subsequently confirmed with the above-mentioned ‘D.M. No. 471/1999’ Decree) (Andreottola and Tatàno, 1993a), different regional comparative risk analysis criteria have been developed in Italy during the past few years (D’Aprile, Marella and Tatàno, 2004).

The ‘*Lombardia Risorse, LR’ Criterion* was originally developed whit the aim of comparing contaminated sites identified in Lombardy Region. ‘LR’ Criterion has adapted, for the first time in Italy, the international US EPA ‘HRS’ standard (according indeed to the original 1982 version: Section 6). ‘LR’ Criterion takes three contaminant migration pathways into consideration (Groundwater, Surface Water, and Direct Contact), which are characterised by the following factor categories: Contamination Source, Contaminant Vehicles and Receptors. Each category includes a group of factors, whose scores, assigned to the investigated site and summed up, identify the category score. The corresponding three category scores are then multiplied, to finally obtain the Groundwater score, Surface Water Score and Direct Contact score. The Groundwater and

Surface Water scores, normalised to 0–100, contribute to the final Site score (according to an algorithm similar to the U.S.EPA 'HRS' approach), which expressly allows for the definition of intervention priorities.

The '*CSSM, Contaminated Site Screening Model'* was developed – in its first version – focusing on the Sicilian survey for contaminated sites, and successively updated (Table 1). 'CSSM' criterion defines, for each investigated site, two different scores:

1 The Site score (P_{site}), obtained through an algorithm similar to US EPA 'HRS', based on Groundwater (P_{gw}), Surface Water (P_{sw}) and Air (P_a) scores, is used for defining a priority intervention list.

2 The Direct Contact ('P_{dc}') score is also obtained separately, which is useful for defining urgent situations of intervention (reducing the immediate risk for human health and/or the environment). As a possible perspective for further updating the 'CSSM' criterion, 'DRASTIC' parametric system (for the assessment of groundwater intrinsic vulnerability: Aller et al., 1987) could be properly replaced in groundwater scoring with the more reliable (for the Italian condition) 'SINTACS' system, as expressly defined and largely applied to the Italian hydrogeological situation (Civita and De Maio, 2000).

The '*Piedmont Region, PR' Criterion* was originally developed for the elaboration of first version of Piedmont and Sicilian Regional Priority Lists for contaminated sites. Then, it was updated, as part of the new version of the Piedmont Regional Clean-up Plan, according to the Italian Technical Regulation 'D.M. No. 471/1999'. 'PR' Criterion does not consider the usual subdivision of hazard calculation in different migration pathways, but only defines a unique risk index 'P' based on the sum (as for Canadian 'NCS': Section 6) of the numerical values assigned to 24 factors characterising the investigated site, with specific weights associated to the given factors. According to 'PR' score sheet, the considered factors are officially subdivided into the following additive factor categories: Remedy Register Site Characteristics, Site Characteristics, Waste Characteristics, Site Environmental-Sanitary Hazard and Sanitary-Hygienic Site Condition. 'PR' Criterion has been also adapted, in the so-called *CR Version*, for the Campania Region situation on contaminated sites.

Also a regional ranking criterion has been developed by the Regional Environmental Agency of Marche Region (ARPAM) as a possible system for hazard comparison of contaminated sites located in this Italian Region. The so-called *ARPAM Criterion* has a calculation approach similar to 'LR' and 'CSSM' criteria, with three migration pathways (Soil – Direct Contact, Ground and Surface Waters) and three factor categories (Contamination Source, Vehicle of Contamination, Human and/or Environmental Targets).

Finally, the so-called *A.R.G.I.A. Method* has been developed by the Regional Environmental Agency of Emilia-Romagna Region to elaborate a priority list of the contaminated sites included in the regional register. The method takes into account both the above-mentioned 'RBCA generic-Tier 1' (Section 4) and 'HRS' (Section 6) criteria, developing a specific conceptual model and logical framework. The A.R.G.I.A. Method defines a unique risk index 'IR', as the sum of the risk indexes for each contaminant calculated for no. 5 migration pathways (Groundwater/Ingestion, Surface Water/Direct Contact, Soil/Direct Contact + Ingestion, Air/Indoor Inhalation, Air/Outdoor Inhalation) as the sum of the products of the scores related to Sources, Transport/Pathways and Receptors categories.

Table 1 Example of synthetic score-sheets for Italian regional comparative risk analysis criteria (D'Aprile, Marella and Tatàno, 2004): the Contaminated Site Screening Model – CSSM (Andreottola and Tatàno, 1993b). Legend: CRW = Category Relative Weight (Section 7); sqr = square root

Factor categories and factors	*Maximum value*	*CRW (%)*	*Factor categories and factors*	*Maximum value*	*CRW (%)*
GroundWater (GW) migration pathway			***AIR (A) migration pathway***		
Source (S)			*Source (S)*		
1. Toxicity / Solubility	160	40	**1**. Toxicity	200	50
2. Waste quantity	80	20	**2**. Waste quantity	100	25
3. Containment	80	20	**3**. Containment	100	25
4. Waste physical state	80	20	**4**. S (lines **1** + **2** + **3**)	400	–
5. S (lines **1** + **2** + **3** + **4**)	400	–	*Transport Vector (V)*		
Transport vector (V)			**5**. Particulate mobility	100	50
6. D: depth to aquifer	50	25	**6**. Gas mobility	100	50
7. R: net recharge	36	18	**7**. V (lines **5** + **6**)	200	–
8. A: aquifer	30	15	*Targets (T)*	–	–
9. S: soil	20	10	**8**. Land use	100	50
10. T: topography	10	5	**9**. Distance to town	60	30
11. I: insaturated zone	50	25	**10**. Distance to sensitive environment	40	20
12. C: hydraulic conductivity	30	15	**11**. T (lines **8** + **9** + **10**)	200	–
13. V [(lines **6** + · · · + **12**) – 26]	200	–	*A score*	100	–
			Pa = (lines **4** × **7** × **11**) × 100/16,000,000		
Targets (T)					
14. Groundwater use	200	100	***Direct Contact (DC) pathway***		
15. T (line **14**)	200	–	*Source (S)*		
GW Score			**1**. Toxicity	280	70
Pgw = (lines **5** × **13** × **15**) × 100/16,000,000	100	–	**2**. Containment	120	30
			3. S (lines **1** + **2**)	400	–
SurfaceWater (SW) migration pathway			*Transport vector (V)*		
Source (S)			**4**. Waste area/Site accessibility	200	100
1. as in GW	400	–			
Transport vector (V)			**5**. V (line **4**)	200	–
2. Run-off potential	50	25	*Targets (T)*		
3. Site slope/Run-off pathway slope	50	25	**6**. Land use	80	40
			7. Relation with public roads	40	20
4. Distance to nearest surface water	100	50	**8**. Distance to town	50	25
5. V (lines **2** + **3** + **4**)	200	–	**9**. Distance to sensitive environment	30	15

Table 1 Example of synthetic score-sheets for Italian regional comparative risk analysis criteria (D'Aprile, Marella and Tatàno, 2004): the Contaminated Site Screening Model – CSSM (Andreottola and Tatàno, 1993b). Legend: CRW = Category Relative Weight (Section 7); sqr = square root (continued)

Factor categories and factors	*Maximum value*	*CRW (%)*	*Factor categories and factors*	*Maximum value*	*CRW (%)*
SurfaceWater (SW) migration pathway			***Direct Contact (DC) pathway***		
Targets (T)			*Targets (T)*		
6. Surface water use	140	70	**10**. T (lines **6** + **7** + **8** + **9**)	200	–
			DC score		
7. Distance to sensitive environment	60	30	Pdc = (lines **3** × **5** × **10**) × 100/16,000,000	100	–
8. T (lines **6** + **7**)	200	–	***CSSM site scores***		
SW score			Psite = sqr $[(Pgw^2 + Psw^2 + Pa^2)/3]$;	100	–
Psw = (lines **1** × **5** × **8**) × 100/16,000,000	100	–	Pdc		

A critical comparative analysis among the Italian regional hazard ranking criteria, using either an additive (as 'PR' and 'CR' approaches) or a multiplicative (as instead 'LR', 'CSSM' and 'ARPAM' approaches) scoring method, can be easily carried out on the basis of the following comparative indexes (Andreottola and Tatàno, 1993a; D'Aprile, Marella and Tatàno, 2004):

- The *Category Relative Weight (CRW)*, calculated – for each factor – as (factor score of maximum hazard effect/category score of maximum hazard effect) × 100.
- The *Pathway Relative Weight (PRW)*, calculated – for each category – as (maximum category score/maximum not normalised pathway score) × 100.

In fact, these indexes reflect respectively the relative importance of a given factor within its proper category, or a particular category within its corresponding migration pathway (or overall hazard route). For instance, the score sheet of Table 1 is comprehensive of CRW values for 'CSSM' criterion. Additionally, CRW values for the remaining Italian regional criteria, as well as PRW values also in comparison with the relevant international hazard ranking standards (Section 6), are detailed in (D'Aprile, Marella and Tatàno, 2004).

Conclusively, the strict dependence of these regional comparative risk analysis criteria from the adopted procedure and different weights of input parameters has shown the need in Italy of unique standards and guidelines. These are now being developed by APAT in cooperation with other scientific institutes, to give a common evaluation tool to the regional environmental authorities for the application of comparative risk analysis for contaminated sites at their regional levels (D'Aprile, Marella and Tatàno, 2004).

8 The 'comparative risk analysis' at EU level: a short summary

As far as the European situation is concerned, recently national preliminary and simplified comparative risk assessment methodologies have been officially documented and reviewed for Denmark, Finland, France, The Netherlands and Sweden, and also two regional approaches for both Germany and the UK, respectively (EEA, 2004a). Precisely, these methodologies are comprehensive of (EEA, 2004a): the Finnish '*GTK, Geologian TutkimusKeskus' Method* (yet in pilot phase, and aimed at ranking risks posed by mining sites); the Swedish '*M.I.F.O., Method for Inventories of Contaminated Sites*' (with quite graphical scoring assessment, and intended to provide a national basis for setting of priorities and decisions on additional investigations and remedial actions); the Dutch '*R.U.M., Remediation Urgency Method*' (which indeed, on the contrary of other comparative risk approaches, does not exactly use a risk scoring routine, but instead applies analytical models and equations more typical of absolute risk assessment protocols); the already above-mentioned French '*S.R.A., Simplified Risk Assessment*' (with seven score sheets: groundwater, potable use; groundwater, other than potable use; groundwater, with no present use, but as a future resource; surface water, potable use; surface water, other than potable use; surface water, with no present use, but as a future resource; and soil) (Subsection 2.4); the Danish '*S.P.P.S. Geoenviron, System for the Prioritisation of Point Sources*' (with a quite multiplicative structure, and the following final indexes: final land use risk score, final groundwater risk score and final surface water risk score); the German regional models '*AGAPE*' (developed by the Hamburg Environmental Agency, and considering five pathways: groundwater, surface water, air, direct contact and soil) (Krischok, 1998) and '*B.W.M., Baden-Württemberg Method*' (developed by the BW State Environmental Protection Agency, and considering too five pathways: soil-groundwater, soil-plants, soil-human health, soil-air and soil-surface water); finally, the UK regional models '*D.R.E.A.M., Dundee Risk Evaluator Assessment Model*' (developed by the Dundee City Council, and based on five so-called 'Pollutant Linkage Scores': human health, surface water receptor proximity, aquifer protection, ecological receptors and designated property receptors) and '*R.R.S.M., Receptor Source Proximity Relative Risk Screening Model*' (developed by the Eden District Council, and characterised with two assessment stages: prioritised receptors and inferred pathways).

Consequently, based on a critical review of international and European (including regional Italian: Section 7) comparative risk assessment models, at the EEA level, recently the '*PRA.MS*' *approach* ('Preliminary Risk Assessment Model for the identification and assessment of problems areas for Soil contamination in Europe') has been proposed (in final draft version) as a scoring criterion to rank sites towards the identification of problem areas (EEA, 2004b).

9 Conclusions

The environmental problem of local soil (and groundwater related) contamination is concerned seriously by almost all European countries. The increasing awareness of local soil contamination problem is leading to the recognition that *soil is a limited resource* and, therefore, requires specific protective and preventive actions in order to maintain all its multi-functionality.

Within each management plan for contaminated sites (finalised to their identification and registration, investigation and eventually final remediation) at a given territorial scale (provincial, regional or national), the application of soil and groundwater quality criteria is an indispensable step. Basically, the different approaches for soil and groundwater quality, developed in the most industrialised countries, can be easily included into two main categories:

1 the *limit value criterion*

2 the *risk analysis criteria*, distinguished into two sub-classes (*absolute* and *comparative* risk analysis).

It appears fundamental to point out that, within a provincial, regional or national management programme for contaminated sites the definition and application of these quality criteria should be based on uniform, scientifically defined and strictly related approaches, if possible. In this perspective, eventually the future promulgation of a specific EU legislation on contaminated soil management (even within a more general soil framework directive) could be the 'motive power' to start a desirable harmonisation (at least, fulfilling a minimum common basis) of the different country approaches on local soil contamination, as indeed it is already the positive European experience for other environmental media (water framework directive, wastewater directive, different municipal and hazardous solid waste directives).

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Any attempt to exhaustively summarize the state of the art of modern macro-comparative linguistic studies within the limits of a short paper would result in inevitable failure. Not even the most informed linguist these days could lay claim to being fully aware of everything that is going on in this field.Â Problem 1: Quantity or quality? This dilemma, as a rule, tends to be resolved in extremities.Â Traditionally oriented historical linguists seem rather slow to embrace these new methods â€" not only because many of them have trouble assimilating the mathematical apparatus, but also because even some of those who do not have any such trouble still feel skeptical about whether machine-based methods are powerful enough to achieve results which the human mind cannot achieve on its own (after all Request PDF on ResearchGate | Development of quality objectives for contaminated sites: State of the art and new perspectives | Local soil contamination, mainly associated with industrial facilities (both in operation and after closure), uncontrolled (industrial and/or municipal) waste landfills, mining and diffused leaching underground storage tanks and pipelines, is an actual and relevant...Â Soil pollution and site management policies have been approached from both conceptual and practical perspectives through risk assessment protocols, cleanup criteria, stakeholder engagement, and liability and funding issues (Wernstedt and Hersh 1998;Ferguson 1999;Sousa 2001;Provoost et al. One of the objectives, the solution of which will serve as a powerful stimulus for the development of scientific and technical base, will be the profound research and the development of mineral resources of the Moon. This, in turn, would entail the establishment of close contacts with other â€œextraterrestrialâ€ intelligent races and cosmic civilizations.Â This will become a powerful stimulus for the development of terrestrial technologies in all areas - from space exploration to meeting of everyday industrial, social and household needs, as well as the development of various biochemical, biological, genetic and quantum micro-field processes.Â It will affect all areas of our lives, beginning with cinema, art, media and internet resources.