

“BABEȘ-BOLYAI” UNIVERSITY  
OF CLUJ-NAPOCA

Faculty of Environmental Science and  
Engineering

**ENVIRONMENTAL RISK ASSESSMENT  
FOR INDUSTRIAL SITES HISTORICALLY  
CONTAMINATED WITH CHEMICAL  
POLLUTANTS**

-Ph.D. THESIS SUMMARY-

PhD. Coordinator:

Prof. dr. eng. Alexandru Ozunu

PhD Student:

Ileana – Codruța Stezar

CLUJ-NAPOCA - 2012



UNIUNEA EUROPEANĂ



GUVERNUL ROMÂNIEI  
MINISTERUL MUNCII, FAMILIEI ȘI  
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*In the summary of the PhD thesis are presented a part of the results of my own practical research, general conclusions and selective references. For the summary redaction were kept the same numbering of the chapters, paragraphs, figures, tables and equations used in the text of the PhD thesis.*

**Key words:** *Risk assessment, contaminated sites, industrial areas, decision support systems, management methodology*

## **CHAPTER 1. Introduction and overview**

### **1.1. Introduction**

*"The final scope of any theory is to assure that the irreducible basic elements are as simple as possible and reduced as number, without being necessary to give up an adequate representation, not even one experiment". **Albert Einstein***

#### **1.1.1. Background and motivation**

Past and present activities such as mineral exploitation and mining, production of electrical power, industrial activities, accidental or intentional use of nuclear material in civil or military activities, or other such, lead to a legacy contamination of lands and ecosystems (EC, 2006a; MMP, 2007a; Dixon et. al., 2007). This statement is sufficient to raise the status of contaminated sites assessment and management along the most critical objectives of politics and practices. Even more, the regulations and politics regarding environmental protection give priority to contaminated resources rehabilitation, such as soil or water, rather than exploiting natural resources. As a consequence, the rehabilitation of contaminated sites or potentially contaminated sites is preferred detrimental to the development of agricultural or natural areas known as greenfields. This fact is well known in most of the European states due to the fact that the open green spaces are more and more reduced as a consequence of intensive land-use (Dixon et. al., 2007; NICOLE, 2008; US Sustainable remediation forum, 2009; Latawiec et. al., 2010; ICCL, 2011).

The statistics present the importance of assessment and rehabilitation of contaminated sites. A recent report of the European Environmental Protection Agency estimates that potentially pollutant activities were developed on almost 3 million sites in Europe, of which approximately 250.000 sites were appreciated as needing remediation. On the other hand, more than 80.000 sites were remediated in the last 30 years in the European countries, where information regarding remediation are available. The European countries are not the only ones facing a wide number of contaminated sites. It is estimated that only in the USA there are more than 450.000 contaminated sites that require remediation (EEA, 2007a).

Darmendrail et. al. (2011) state that up to now, the evolution of politics regarding the management of contaminated sites had three important stages:

- *first generation: in the years 1980* (involve a drastic risk control, systematic approaches, priorities focused on soil contamination); these still can be found today at national level;
- *the second generation: in the years 1990* – risk assessment for contaminated lands (the possibility of elaborating specific approaches, assurance of a safe reuse for the receptors and stopping the degradation, eventually improvement of environmental factors);
- *the third generation: după 2000* – Risk-based land management (integration with land-use planning, water management, the socio-economic factor).

The newest progress and perception/approach includes the application of the quality objectives that can be attained if are taken into account the efficient solutions from the point of view of costs and principles regarding human health and environmental protection, based on sustainable development (CLARINET, 2002a,b,c; ICCL, 2011).

Taking into account all these general issues regarding the management of contaminated sites, what becomes urgent to include the sustainable development principle in a real decision-making process is the correct identification of the area of interest and establishment of a suitable management methodology (Ozunu et. al., 2009; Olah et. al., 2012). Thus, the present work, proposes a methodology in this way, taking into account the existent regulations in the field at Romanian level.

### 1.1.2. Objectives

The current paper deals with a highly interest thematic both at national and international level, due to the fact that at mondial level it is estimated that potentially polluting activities have been developed on millions of industrial sites, of which just a small part benefited of investigation and assessment actions to determine the level of pollution and the areas that need remediation. The European and national context in which the concerns for soil protection, its sustainable use, conservation and where adequate the restoration of its capacity of fulfilling as much of its functions, is under a significant ascendent evolution. The scope of the work is to elaborate at Romanian level, a methodology for the management of industrial sites historically contaminated based on land-use planning and risk assessment, and its validation by implementing it on a case study (the former industrial site Tractorul Braşov), affected by pollution with heavy metals (Cd, Cu, Ni, Mn, Pb, Zn) and total petroleum products - TPH) with the help of decision support systems.

The major objectives of the paper were:

- a) Development of a literature review within sources in USA, EU and Romania, to identify the main relevant issues in the field of industrial contaminated sites management;
- b) Development of a methodology based on land-use planning and risk assessment for the management of industrial sites historically contaminated at Romanian level;

- c) Implementation of the methodology on a case study for its validation;
- d) Comparative analysis of two decision support systems based on risk for the rehabilitation of contaminated sites: SADA and DESYRE, applied on a case study.

## **1.2. Structure of the paper**

The current thesis is structured in eight chapters. In chapter 1 the introductory part of the paper is described, in chapters 2-3 the theoretical aspects exemplified by practical applications are presented, and in chapters 4-7 the main practical parts of the paper are described, and chapter 8 presents the general conclusions, original contributions and potential future work.

Chapter 1 presents the motivation of choosing the theme, supported by the general and specific objectives, along with the description of the methodology for elaborating the current thesis. At the same time, taking into account the fact that the main pillars of this thesis are the management and environmental risk assessment for the industrial sites historically contaminated, in this chapter are stated the principles regarding these two concepts.

Chapter 2 unfolds the framework of politics and current legislation in the field, in USA, EU and Romania. Aspects related to the proposal of a framework directive for soil at EU level were presented, the implementation of national politics in member states, the evolution of the domain and the current state-of-the-art in USA. Coordination agencies, forums, organisations and programmes developing several activities in connection with this field were also presented. Nonetheless, the author analysed the current situation existent at Romanian level, presenting briefly the public inventory in the reports of the environmental protection agencies, and issued recommendations for the improvement of the field at national level.

In what regards the importance of contamination hazards and risks, in chapter 3 were presented the main methodologies for the management of contaminated sites applied internationally, explaining also the main fields of activity and respectively the rate of the substances involved, at EU level. The aspects related to the primary contamination sources and the main contaminants of interest were elaborated taking into account the case study application in chapter 6. The concepts of hazard and risk in the field were discussed, focusing on the necessity of elaborating a conceptual site model, the chapter ending by presenting the importance of the threshold values in analysing and industrial site historically contaminated; an analysis at Romanian level was also developed, being given recommendations and suggestions. At the same time in this chapter are described the main aspects related to site specific risk assessment, respectively regional risk assessment are described. Site specific risk assessment is detailed by human health risk assessment, respectively ecologic risk assessment. All these are presented based on their connection with the field of contaminated sites. Nevertheless, the main uncertainties that can occur during these analyses are presented. Likewise, in this chapter was presented the importance of using decision support systems in the field of historically

contaminated sites management, and the two DSS SADA and DESYRE were described, these being used subsequently for the applications in chapters 6, respectively 7 of the thesis.

Chapter 4 exposes in the first phase the the main decision-making approaches that can influence the management of industrial sites historically contaminated. It continues by presenting the aspects related to land-use planning at international level, respectively in Romania. The author proposed in this chapter the classification of land-uses in the law of land fund based on risk criteria and in association with the uses inventoried at EU level. Not least, in this chapter was developed a sociological survey with the scope of presenting the opinions and level of development for contaminated sites at Romanian level, based on the experience of stakeholders involved in the process (academia, private sector, authorities). The results of the survey were also used for developing the methodology proposal for the management of industrial sites historically contaminated based on risk assessment and land-use planning, in chapter 5.

One of the main products of this thesis is the methodology proposal for the management of industrial sites historically contaminated based on risk assessment and land-use planning, in chapter 5. The successive steps are presented and applied in an integrated way. The methodology proposal was developed taking into account the current legislation into force in the field at Romanian level, as well as other 3 methodologies applied at international level.

Chapter 6 presents the practical application of the methodology proposed in chapter 5, on a case study. The selected study is the former industrial site S.C. Tractorul S.A. Braşov. Are presented the results obtained for each of the steps of the proposed methodology by applying them on the case study. The author did for obtaining these results several site visits, had discussions with the environmental representative of the site developer and environmental authorities in Brasov, and nonetheless with the contractors who executed services for different steps of the proposed methodology.

In chapter 7 the comparative analysis of two decision support systems based on risk for the rehabilitation of contaminated sites: SADA and DESYRE applied on a case study, the former industrial site S.C. Tractorul S.A. Braşov. The scope was to present the benefits of using decision support systems, so as to introduce, process and disseminate the results to different stakeholders involved in the decision-making process for the management of industrial sites historically contaminated. Were comparatively analysed the results, models used, modules included in the analysis and the potential uncertainties.

The general conclusions, original contributions and future work are presented in chapter 8.

The original results of the PhD thesis were disseminated as follows: 4 articles published in ISI Web of Science Journals, 4 articles being evaluated in ISI Web of Science Journals, 4 articles published in national recognized journals, 5 papers presented as oral communications and 2 papers presented as posters at national and international conferences.

### **1.3. Methodology of the paper**

The thesis is characterized by an exploratory and complex research which included different sources as books, journal papers, internet, information and material from the authorities, participation at scientific events, and last but not least open discussion and interviews with experts in the field.

### **2.3. Situation at Romanian level**

#### **2.3.1. Existent initiatives**

As support for the development of rehabilitation actions and inclusion in the urban circuit of sites, different projects and programmes for the management of historically contaminated sites offer financial support (MMDR, 2007).

In the project PHARE 2006/018-147.03.03/4 “Technical assistance for preparing a strategy and an action plan for the rehabilitation of historically polluted sites” after the preselection and prioritization stages of historically contaminated sites, in the third stage the following sites were selected, for which were prepared financial applications in the POS Mediu project, and currently rehabilitation works were contracted:

1. Site of a former chemical plant (Crângurile City Hall)– chemical industry domain;
2. Petroleum waste heap Peștelui Lake (Câmpina City Hall) –extractive and process domain;
3. Hazardous substances deposit UCT – Poșta Rât (Turda City Hall) –POPs domain.

In 30 October 2007, Haskoning Nederland BV Environment Holland, in the project for elaborating a National Strategy for the Administration of Contaminated Sites, elaborated the report draft version 1, National Inventory of Contaminated Sites, Technical Guide National Inventory (MMDR, 2007), beneficiary being the Ministry of Environment and Sustainable Development (currently the Ministry of Environment and Forests).

According to this study, the proposal of a strategy regarding the management of contaminated sites in Romania, published in 2008 included a legal framework and a complete methodology in order to develop a preliminary inventory and to establish priorities based on risk assessment associated to potentially contaminated sites.

At the same time, for an efficient support to collect, storage and administrate the recorded information, an Informational System was developed to allow users to access, upgrade and visualize data regarding the contaminated sites in Romania: Information Inventory System for Contaminated Sites (CoSIS).

According to the proposal of a National Strategy for the management of Contaminated Sites in Romania, version 2011, currently there are 1865 inventoried potentially contaminated sites, registered in the CoSIS 2.0 database administrated by the National EPA; this will include the national inventory for all the potentially contaminated sites.

In accordance with the legal provisions of HG. 1076/2004 regarding the establishment of the procedure to develop environmental assessment for plans and programmes, it was done the step of framing for the proposal of the National Strategy for the Management of contaminated sites, version 2011, but it was rejected (MMP, 2011).

### **2.3.2. Evolution of contaminated sites inventory at Romanian level**

Due to the fact that the proposal of a strategy regarding the management of contaminated sites issued in 2011 was rejected (because it did not identify the objective of the document, namely contaminated sites), it is now considered important to develop, as efficiently as possible, the site inventory.

According to the information from National EPA, the development of the national inventory for contaminated sites begun in 2006. Based on the data in (i) the Annual Reports regarding environmental factors condition of the National EPA during 2006-2009, (ii) the Annual Report regarding environmental factors condition of the eight Regional EPAs in 2010, and (iii) the data in the presentation made by Eng. Ioan Baceanu PhD., in October 2011 at the SarmaProject workshop, Bucharest, the authors developed a statistical evolution of this inventory for the period 2006-2011. The results are presented in *Table 2.5*.

Table 2.5. Potentially contaminated/contaminated sites inventory for the period 2006-2011 in Romania

<b>Inventory of potentially contaminated sites</b>									
<b>Region/Report</b>	1 NE Bacău	2 SE Galați	3 S Muntenia Pitești	4 SW Oltenia Craiova	5 W Timișoara	6 NW Cluj-Napoca	7 Centre Sibiu	8 București - Ilfov	TOTAL
Report NEPA 2006									
Report NEPA 2007									
Report NEPA 2008 (ha)	786	448	910	468	317	421	355	101	<b>3806</b>
Report NEPA 2009	33	33	0	15	77	153	49	5	<b>365</b>
Reports REPA 2010	148	105	?	257	157	255	47	7	<b>976*</b>
PPT**2011	503	497	533	205	231	253	241	57	<b>2520</b>
<b>Inventory of contaminated sites</b>									
<b>Region/Report</b>	1 NE Bacău	2 SE Galați	3 S Muntenia Pitești	4 SW Oltenia Craiova	5 W Timișoara	6 NW Cluj-Napoca	7 Centre Sibiu	8 București - Ilfov	TOTAL
Report NEPA 2006	155	383	155	71	129	65	81	13	<b>1052</b>
Report NEPA 2007	155	395	150	229	190	92	107	21	<b>1339</b>
Report NEPA 2008 (ha)	111	72	321	104	33	65	75	7	<b>788</b>
Report NEPA 2009	111	72	321	104	33	65	75	7	<b>788</b>
Reports REPA 2010									
PPT**2011									

Note:

\* without taking into account region S Muntenia Pitești.

\*\*PPT – presentation of eng. Ioan Baceanu PhD., in October 2011 at the SarmaProject workshop, Bucharest (inventory established based on the number of questionnaires sent to the economic agents and local authorities that own such sites)

### 2.3.3. Potential improvements at national level

Taking into account the fact that at national level the privatization period was later than in West European countries, reason why the management of contaminated sites became a necessity and priority at a later time, the needs and potential of improvement in the field are high.

Taking into account the situation in *Table 2.5*, it can be observed that the inventoried data are difficult to analyse as they present in a scanty way the situation at national level. The lack of a unitary method of presenting the data by the regulatory authorities may lead to different interpretations and misunderstandings in regard to the terms used to define these sites, namely, contaminated, potentially contaminated and possibly contaminated. What is not very clear is the context in which these terms are used, and so it is difficult to distinguish, in certain situations, the contaminated sites from the potentially contaminated ones. At the same time, the data are not consistently reproduced, namely in some reports they are presented as the areas occupied by these sites, or their number, or the site activities that could have led to the land contamination.

Nevertheless, another important aspect to be mentioned is the fact that in the EPA reports it is stated that not all these sites can be referred to as needing a pollution investigation and assessment in accordance with the current regulations, but only in terms of establishing the presence of historical pollution. This implies the possibility that some areas could be monitored as contaminated sites without taking into account the natural environment quality of attenuation; respectively some modifications might have occurred from the date of the last environmental study regarding the situation on the analysed sites.

Due to the fact that at EU level the Soil Framework Directive is a proposal, each of the member states has its own specific legislation regarding the management of contaminated sites. Previously in this chapter it was detailed the existent legislative situation in the field in Romania, as well as aspects in USA and EU member states. Based on these information the following recommendations are proposed for the improvement of the management in the field at national level, namely (**Steazar et. al., 2012c, Steazar și Ozunu 2012e**):

- issue of several guidelines/technical documents regarding the inventory, investigation, risk assessment, remediation and post-remedial monitoring of historically contaminated sites;
- upgrade of the threshold values regarding land investigation, these being issued since 1997; these criteria should be established taking into account both land-use planning and risk assessment aspects (source-pathway-receptor analysis); the adaptation and application of new rehabilitation standards should combine both;
- human health and ecologic risk assessment methodologies should be clearly defined, detailed and eventually adapted to the ones used internationally;
- detailed specification of the methodological parameters needed for risk assessment (physical, chemical, hydrogeological, climate, toxicological, exposure parameters);

- elaboration, implementing and maintaining some management and operational procedures regarding contaminated/potentially contaminated sites management for the authorities in the field, which to include provisions regarding quality, environment and/or information security management (establish the procedures to collect, process, validate, storage and upgrade the data; identification of data/information sources; establishment of collaboration modalities with institutions that hold data/information regarding soil and subsoil quality;
- reissue of the national inventory questionnaire by the Ministry of Environment and Forests, setting of a filling-in schedule and transmission to site owners;
- dissemination of courses and/or trainings in the field for stakeholders involved in the decision-making process;
- elaboration of a geochemical atlas, similar to the one developed for Iasi and surroundings (Iancu și Buzgar, 2008), respectively Heredea, (2011) for the three regions, as well as the analysis of Dumitru et. al., 2011;
- elaboration based on the information in the CoSis database (or on the reports of ANPM, ARPM, APM) of several maps with the regional distribution of the inventoried sites and the level of pollution, type of pollution (pollution sources, types of pollutants etc.).

#### **4.3.2. Land-use planning for a sustainable management of contaminated sites in Romania**

Taking into account the fact that industrial sites historically contaminated redevelopment involves the concept of land-use planning, and that at the level of other EU member states the analysis of these sites is done based on the future use attributed on risk criteria, further on are discussed aspects relevant from the field at Romanian level. At the same time a classification of land use based on risk criteria is proposed.

As previously presented, in *Table 3.2.*, subchapter 3.2.3., in most of the European countries there is a system for the classification of land uses.

Considering the national legal provisions regarding the management of contaminated sites and land-use planning, further on are comparatively presented the land uses, in correlation with the ones used in EU.

It is also made a correlation with the land uses presented in the DSSs SADA and DESYRE, these two being used in the applications for the analysed case study in the thesis (Steazar et. al., 2012a).

Based on the aspects comparatively presented in *Table 4.2.*, the thesis proposes a classification on categories of land-use, which to be used for contaminated sites management with the scope of allowing the analysis of future land-use on risk criteria (*Table 4.3.*). The proposed uses are industrial, agriculture, residential and recreational. These are set for each of the land-use categories determined at legislative level. So as to have a correlation also with the provisions of the Decree 756/1997, the agricultural, residential and recreational uses are

considered to be sensitive land-uses and the industrial one less sensitive (Steazar și Ozunu, 2012 b).

Table 4.3. Proposal of land-uses and their coding considering risk assessment for contaminated sites

Land-use categories	Subcategories	Code	Proposed land-use
<b>Arable land (A)</b>	<i>arable</i>	A	Agricultural use
	<i>cultivated meadow</i>	AP	Agricultural use
	<i>vegetable gardens</i>	AG	Agricultural use
	<i>greenhouses</i>	AS	Agricultural use
	<i>solariums and glazing units</i>	ASO	Agricultural use
	<i>other perennial cultures</i>	ACP	Agricultural use
<b>Pastures (P)</b>	<i>Clean pastures</i>	P	Agricultural use
	<i>Pastures with forests</i>	PP	Agricultural use
	<i>Pastures with trees</i>	PL	Agricultural use
	<i>Pastures with shrubbers and briers</i>	PT	Agricultural use
<b>Hays (F)</b>	<i>Clean hays</i>	F	Agricultural use
	<i>Hays with trees</i>	FL	Agricultural use
	<i>Hays with forests</i>	FP	Agricultural use
	<i>Hays with shrubbers and briers</i>	FT	Agricultural use
<b>Vineyards (V)</b>	<i>vineyards</i>	V	Agricultural use
	<i>Noble vineyards</i>	VN	Agricultural use
	<i>Hybrid vineyards</i>	VH	Agricultural use
	<i>Hop plantations</i>	VHA	Agricultural use
	<i>Vineyard plantation</i>	VP	Agricultural use
<b>Orchards (L)</b>	<i>Classic orchards</i>	L	Agricultural use
	<i>Intensive and superintensive orchards</i>	LI	Agricultural use
	<i>Orchards plantation bushes</i>	LPA	Agricultural use
	<i>Mulberry tree plantations</i>	LD	Agricultural use
	<i>Tree nursery</i>	LP	Agricultural use

<b>Forests and other forestry lands (PD)</b>	<i>forests</i>	PD	Agricultural use
	<i>Protection lines</i>	PDP	Agricultural use
	<i>Shrubbery and brakes</i>	PDT	Agricultural use
	<i>Forest nursery</i>	PDPS	Agricultural use
<b>Lands with waters and waters with reed</b>	<i>Surface waters-streams</i>	HR	Recreational use
	<i>Natural lakes and ponds</i>	HB	Agricultural or recreational use
	<i>reservoirs</i>	HA	Recreational use
	<i>Fishing developments</i>	HP	Agricultural use
	<i>Waters with reed</i>	HS	Agricultural use
	<i>canals</i>	HC	Recreational use
	<i>Territorial sea</i>	HM	Recreational use
<b>Road communication ways (DR), railways (CF) and airports (AE) and other transport networks (RT)</b>	<i>Highways</i>	DA	Industrial use
	<i>National roads</i>	DN	Industrial use
	<i>County roads</i>	DJ	Industrial use
	<i>Commune roads</i>	DC	Industrial use
	<i>Streets and lanes</i>	DS	Industrial use
	<i>Exploitation roads (agricultural, forestry, petroleum, industrial etc.)</i>	DE	Industrial use
	<i>Touristic roads and paths</i>	DT	Recreational use
	<i>railways</i>	CF	Industrial use
	<i>airports</i>	AE	Industrial use
	<i>Transport networks (petroleum products, gas, sewerage networks etc.)</i>	RT	Industrial use
<b>Land occupied by constructions and yards (CC)</b>	<i>constructions</i>	C	Industrial or recreational use
	Constructions of housing	CL	Residential use
	Administrative constructions	CADM	Industrial use
	Financial banking constructions	CFB	Industrial use

	Commercial constructions	CCOM	Industrial use
	Constructions for cult	CCLT	Recreational use
	Constructions for culture	CCUL	Recreational use
	Constructions for education	CINV	Industrial use
	Constructions for health	CSAN	Residential use
	Constructions and development for sport	CSPO	Recreational use
	Constructions for leisure	CAGR	Recreational use
	Social constructions	CSOC	Residential use
	Industrial constructions	CIND	Industrial use
	Constructions of monuments, historical assemblies	CMAS I	Recreational use
	Turistic constructions	CTUR	Recreational use
	Metro constructions	CMET	Industrial use
	Constructions for utilities	CEDIL	Industrial use
	Annex constructions	CA	Industrial or residential use
	Industrial and utility constructions	CIE	Industrial use
	Administrative and social constructions	CAS	Residential use
	<i>Yards and constructions</i>	CC	Industrial or residential use
	embankments	CD	Industrial use
	quarries	CA	Industrial use
	parks	CP	Recreational use
	graveyards	CI	Recreational use
	Sport areas	CS	Recreational use
	Markets and fairs	CT	Industrial use
	Meadows and swimming pools	CPJ	Recreational use

	Embankments with stone	CTZ	Industrial use
	Frontier area	CFF	Agricultural use
	Mining and petroleum exploitations	CMP	Industrial use
	Other lands with constructions	CAT	Industrial use
<b>Degraded and unproduced lands (N)</b>	<i>Flying sands</i>	NN	Recreational use
	<i>Boulders, cliffs, gravels</i>	NB	Recreational use
	<i>gulches, gaps, torrents</i>	NR	Recreational use
	<i>Bitterns with crust</i>	NS	Recreational use
	<i>Marshes and swamps</i>	NM	Recreational use
	<i>Pits and dumps</i>	NG	Industrial use
	<i>Waste heaps</i>	NH	Industrial use

#### 4.4. Sociological survey for supporting the methodology proposal

In preparing this study, there were direct discussions with stakeholders in the management of contaminated sites from academia, research, consultancy, private sector and authorities in Romania, Italy and England. In addition to these direct meetings, a survey was conducted through a sociological questionnaire (Annex 1.) which was applied to 130 Romanian stakeholders involved in the management of contaminated sites. (Steazar et. al., 2012c, Steazar și Ozunu, 2012e).

As stated above, to capture the perceptions and attitudes towards the management of contaminated sites, we conducted a postal questionnaire which was to be filled in both by domain experts and other stakeholders in the process (national authorities, researchers and academics, freelance experts and the operators in the private sector).

The main steps taken to perform the survey were:

##### 1. Establishing the project scope

The project goal is to present the opinions on the development level of contaminated sites management in Romania through the experience of the primary stakeholders involved in this process. At the same time the results will be used to develop the proposal of a methodology for the management of contaminated sites based on risk assessment and land-use planning, presented in chapter 5.

## **2. Identification of subjects**

Stakeholders involved in filling in the questionnaire are:

- environmental consultants/experts (environmental assessors / auditors certified in Romania);
- governmental authorities (Environmental Protection Agencies (EPA)– local, regional, national level, Ministry of the Environment and Forests (MEF), Ministry of Regional Development and Tourism (MRDT));
- academia (universities),
- research institutes,
- private sector (owners/developers of potentially contaminated sites), and
- contractors (accredited analysis laboratories, geological services providers).

The estimated number at national level of potential participants of interest is about 2,500, most of whom are represented by the owners of potentially contaminated sites (1,856 of potentially contaminated sites according to the proposed Strategy for the management of contaminated sites in Romania, version 2011); the other categories each had, a number of below 100. It should be noted, however that the number of 1,856 was presented without evidence support in the proposed strategy, as outlined in chapter 2; it should also be noted that any operator could hold more than one inventoried site. 130 questionnaires were sent, the selection also taking into account available access to contact details. Response was received from 73 of them (about 56%).

## **3. Choosing how to implement the questionnaire**

Due to the relatively high number of people involved in completing the questionnaire, as well as their diverse locations, they were sent by e-mail, being the same way received after they were filled in.

## **4. Elaboration of the questionnaire**

The questionnaire was elaborated using closed questions (i.e. multiple choice) as well as open ones (which require the respondent to provide an answer). The questionnaire has five parts, namely (i) contaminated site management, (ii) site investigation, (iii) risk assessment for contaminated sites, (iv) remediation and (v) recommendations. The 15 questions were distributed within these sectors, from 1.1. to 6.1.

The questionnaire was analyzed some international experts Mr. David Barry and Mrs. Lisa Pizzol PhD., Ca Foscari University, Venice and a series of people from academia and authorities in Romania, who provided suggestions on aspects that should be modified or completed in the questionnaire form, based on their experience.

## **5. Responding to questionnaire**

Each of the respondents was asked to fill in answers to questions based on their experience in the field. These were completed independently and individually.

## 6. Data analysis

Data were analyzed using SPSS software (Statistical Package for the Social Sciences) version 19 (SPSS, 2012). SPSS for Windows is a software package for statistical analysis of data. Although there is a variety of programs of this kind (SAS, Statistics for Windows, GraphPad, MS Excel, which also has statistical functions), SPSS is distinguished by its rigorous structure and ease of use.

Using SPSS, the responses were analyzed and the percentages recorded for each of the questions. For correct and efficient data processing in SPSS, each question was analyzed to extract from the answers received, common variables and responses, in Annex 2.

The questionnaire response data were processed with the frequency function of SPSS. The results are presented below.

In case of the recommendations, (*Figure 4.13.*), after the analysis of all the questionnaires, categories of recommendations were set based on the data filled in by the questioned subjects, these being (together with the percentages afferent for each of the categories): development of investigations and assessment taking into account the site specificity (50%), development of remedial actions based on risk assessment, cost/efficiency analysis and cost benefit analysis (44%), involvement of all stakeholders in the decision-making process for the management of contaminated sites for a good dissemination and application of results (32%), application of the best remediation technologies (both from scientific point of view, as well as from the point of view of the site specificity) in accordance with the results of the risk assessment and taking into account the sustainable development principle (23%), protecting human health and the environment (25%), taking into account the future land use (48%), instruction and training of stakeholders (19%), establishing the level of uncertainty for all the data used in analyses (12.3%), correct coordination and ranking of the decision-making process (23%), the lack of a complete specific legislative framework and implementation of it in Romania (43%).

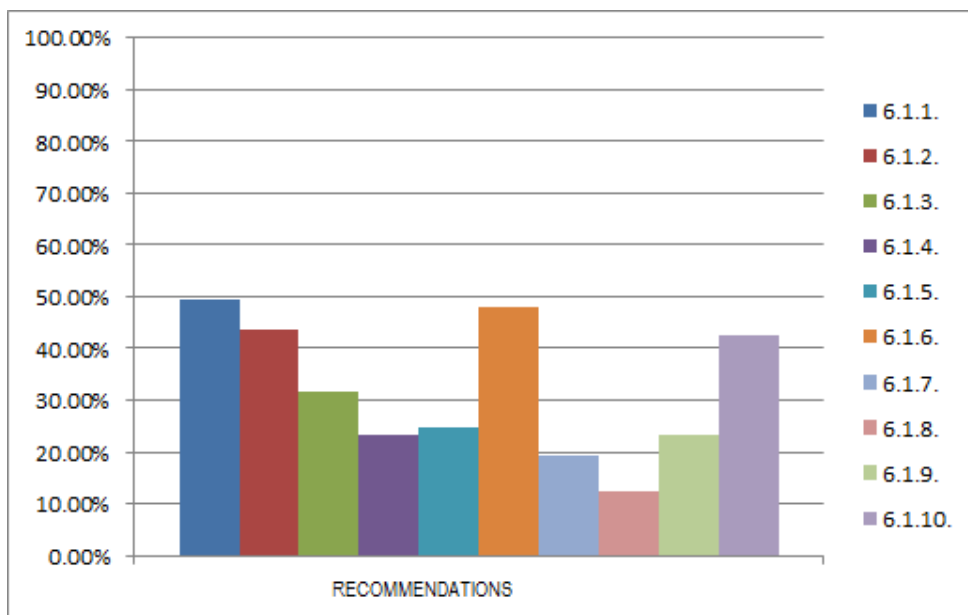


Figure 4.13. Suggested recommendations by respondents regarding the domain of contaminated site management

From the previously mentioned variants, that were differentiated by percentages, it can be observed that the subjects highlight the necessity of developing an analysis based on the specific character of each site, including the risk assessment, cost/efficiency and cost/benefit analysis so as to give efficiency to the best remedial actions, a fair communication between the stakeholders involved. Also, although with lower percentages, it is recommended the systematization and wholeness of the specific legislative framework at Romanian level; as it was mentioned previously chapter 3, at European level there are lacks in what regards the legislative framework for this field of interest, this fact making more difficult the situation for Romania, even though there are several Member States that have an individualized legal framework.

Based on the questionnaire analysis, apart from the specific information obtained for each of the questions, the following general conclusions can be drawn, namely (Steazar et. al., 2012e):

- taking into account that at Romanian level the field of contaminated sites management is relatively new, in 2007 being issued two legislative acts in this way, the stakeholders involved in the decision-making process encounter obstacles in what regards the regulatory issues, research, and lack of practical applications;
- at the same time, in the current legislation there is not made a parallel between the land-use planning and the environmental legislation also applicable in the case of contaminated sites management;
- even though in the Governmental Decision 1408/2007, as well as in the proposal for a technical guide afferent to it, and in the proposals of strategies regarding the management of contaminated sites in Romania it is mentioned the necessity of developing a risk assessment to establish the level and extent of contamination on a site, where we add the results of the questionnaire for

which 100% of the subjects stated that risk assessment is a needed step, there is not available a well-structured and detailed methodology for human health and/or ecological risk assessment (except for the one in the Decree 184/1997, which is extremely simple and full of gaps);

- it is recommended to establish partnerships, to participate in international projects which to include applicative aspects as well as dissemination parts so as to train the stakeholders in Romania involved in this field, based on the experience of other EU Member States.

## **CHAPTER 5. The decision-making process for the management of industrial sites historically contaminated, based on land-use planning and risk assessment**

### **5.1. Introduction**

In this chapter are presented the main aspects related to environmental management, respectively being highlighted the ones referring to contaminated sites field. At the same time it is presented in detail the methodology for the management of industrial sites historically contaminated, based on land-use planning and risk assessment, elaborated in this thesis.

#### **5.2.3. Contaminated sites management**

Knowing the importance of contaminated sites issue, their identification it is not sufficient so as to facilitate decision-making. The decision-making process for contaminated sites assessment and management is controversial and difficult, partially due to different aspects involved (economic interest, environmental restoration, social acceptance, technological appliance, land-use planning, and other influences). Due to these aspects, in the last years, many studies and legislative applications highlighted the definition of the decision-making for contaminated sites assessment and management, such as EEA, (2000); Hill și Zammit, (2000); Bardos et. al., (2001a); Tedd et. al., (2001); Khadam și Kaluarachchi, (2003); Bardos et. al., (2004); Agostini et. al., (2005); Bridges et. al., (2004); Pollard et. al., (2004); CLARINET, (2002a,b,c); EEA, (2011); World Bank, (2010); ICCL, (2011); Darmendrail, (2011).

Taking into account the aspects presented in the previous chapters of the thesis, it can be concluded that the management of contaminated sites is important in two situations:

- either when the issue of effective land use is raised (the assessment of the possibility to use the land according to the proposed scope). In case the conclusions are positive (respectively the land does not require any intervention measure for diminishing the risks due to contamination), the proposed land use can be implemented, while, in case the conclusions are negative the identification of the necessary measures in order to allow the proposed used is needed (remediation, cancelling the project, change of the proposed land use etc.);

- or when the issue of future land use planning is raised (development of urban area plans). In this situation it is important to find the optimum land use in relation with the site specificity.

In this context, it is recommended that the proposed methodology should be applied in the phase of land use planning, and only if this it is not possible, for the validation of some new proposed uses (the change of the current use) (Steazar și Ozunu, 2012b).

### **5.3. Methodology for the management of industrial sites historically contaminated, based on land-use planning and risk assessment**

#### **5.3.1. Scope of the methodology**

The scope of the methodology for the management of industrial sites historically contaminated, based on land-use planning and risk assessment is to substantiate the decision-making process, based on the sustainable development principle, in order to reuse the former industrial sites.

The decision-making process based on risk management for contaminated sites presumes the interconnectivity of the four decision approaches presented in chapter 4 (environmental, economic, participative/deliberative and based on expert judgement).

Mainly the proposed methodology was published in the paper **Steazar și Ozunu, 2012b**.

#### **5.3.2. Aspects of the approach**

The methodology for the management of industrial sites historically contaminated is based on the following legislative regulations:

- HG. 1408/2007;
- HG. 1403/2007;
- Decree 756/1997;
- Decree 184/1997;
- Law 18/1991 of land fund revised, republished in the Official Monitor no. 1 in 5.1.1998, with further modifications and completions;
- Decree no. 534/2001 in 01/10/2001 regarding the approval of the technical regulations for the introduction of general cadaster;
- OUG 7/2011 modification completion Law 350/2001 regarding land planning and urbanism.

At the same time during the literature review were analysed the methodologies RBCA (SUA), CLEA (UK), Dutch Intervention (Holland) (ASTM, 1998; VROM, 2006; NHBC, 2008). These were chosen due to the fact that are used since over 20 years, by countries (including EU

member states), were revised and upgraded on a permanent basis and are all based on risk assessment.

At the same time were taken into account the discussions with experts in the field of contaminated sites management (authorities in Romania, consultants in Romania, UK Italy, academia and research in Romania and Italy).

Nonetheless were also used the results of the sociological survey based on a questionnaire, presented in subchapter 4.5.

An issue considered important in relation with the proposed methodology was the correlation of terms to define the concept of contaminated site.

According to the Governmental Decision 1408/2007 'a contaminated site is geographically defined area, delineated in surface and depth, polluted with biological or chemical substances'. At the same time it is mentioned the fact that the purpose of the detailed investigation and assessment is among others to clarify the nature and intensity of the identified pollution, without specifying the criteria based on which the analysis of this intensity will be done, nor the pollution level above which a site can be considered as being contaminated.

The Decree no. 756/1997 sets the criteria for the analysis of the pollution intensity, respectively:

- 'potentially significant pollution is the existence of some pollutant concentrations in the environment, which are above the alert threshold values established in the regulations regarding environmental pollution assessment. These values define the level of pollution at which the authorities consider that a site can have an impact on the environment and set the necessity of supplementary studies to be done and of measures to reduce the concentrations of pollutants', and
- 'significant pollution is represented by concentrations of pollutants in the environment, above the intervention threshold values stipulated in the regulations regarding environmental pollution assessment'.

By analyzing all the mentioned definitions it can be observed the fact that the concept of 'significantly polluted site' can be clearly defined, while the concept of 'contaminated site' it cannot. Thus, it was taken into account the definition mentioned before given by the proposal of a soil framework directive to the term contaminated site.

Taking into account all the aspects mentioned above, the proposed methodology recommends the use of the term 'significantly polluted site' for the land and aquifer for which the results of the chemical analyses indicate the overcoming of the intervention threshold values (defined by the regulations into force at the moment for soil and groundwater), and of the term 'contaminated site' for the land and aquifer where for which the result of the risk assessment indicates the existence of a significant risk level.

At the same time is mentioned that the methodology is proposed for industrial sites historically contaminated (lands on which the industrial activity was developed previously to the transposition of the IPPC Directive provisions).

## **5.4. Defining the steps of the methodology for the management of industrial sites historically contaminated**

Details regarding the decision-making process and the approaches used were presented in chapter 4.

In Annex 3 is presented the scheme of the methodology for the management of industrial sites historically contaminated based on land-use planning and risk assessment.

The main steps of the proposed methodology are:

- Step I – Land-use planning and socio-economic analysis;
- Step II – Preliminary investigation and assessment;
- Step III – Detailed investigation and assessment;
- Step IV – Risk assessment;
- Step V – Remediation, residual risk management and monitoring.

## **CHAPTER 6. Case study – Application of the methodology for the management of industrial sites historically contaminated, based on land-use planning and risk assessment**

### **6.3. Case study conclusions**

The application of the methodology on the case study had as scope to present its applicability, viability and its validation (Stezar și Ozunu, 2012d).

The case study (S.C. Tractorul S.A.) chosen to exemplify and validate the methodology is sufficiently complex to assure that all the procedure steps of the methodology are covered and it refers to a former industrial site, where activities were developed since 1925, thus a historically polluted industrial site.

The conclusions of applying the methodology proposed in chapter 5 on the case study are presented further on separately for each of the steps.

For the socio-economic assessment step, the proposed future land uses for the former industrial site S.C. Tractorul S.A. Braşov were: industrial, residential and namely, recreational. These uses were attributed to different sectors delineated on the site in accordance with the areal urban plan.

In the preliminary investigation and assessment step the following stages were developed: historical data identification and assessment; analysis of climate, geology, hydrology, hydrogeology and the current state of environmental factors; inventory and analysis of information in the previous elaborated environmental studies. After analyzing the historical data

and the situation on the field were established the potential pollution sources associated to the former or current uses and other local factors. Based on the data analysed from the former studies it is considered that the the main contaminants of interest for the analysed site are Cd, Cu, Pb, Mn, Zn, Ni and TPH. Based on these aspects the preliminary conceptual site model was developed.

In the detailed investigation and assessment step were planned and afterwards elaborated the investigations considered to be necessary taking into account the results obtained in the previous step. A soil and groundwater sampling and analysis plan was developed, meant to give supplementary information sufficiently detailed regarding the level and extent of contamination in the analysed area. Further these sampling and analysis were done in accordance with the plan, and the results obtained were evaluated by specific methods. This investigation plan was done by the site developer through three successive sampling and analysis campaigns, in the period 2008-2009, and were meant to identify, detail and correlate the results with the existent data in what regards the sources and types of contaminants on the investigated area. A comparison of the results with the natural background values was done. Taking into account the large gaps between the highest and lowest concentration values for all the analysed indicators for the soil samples, it was decided to develop a statistical analysis to identify potential uncertain values. These concentration values were identified and it was decided not to be used in the further assessments.

In what regards the analysis of results for groundwater, the flow regime was determined, by modelling, using the software Optimal Well Locator (OWL). At the same time the determined concentration values were compared with those in Law 311/2004, respectively with the values for the groundwater body ROOT02. Interpolations were made for each of the analysed parameters to graphically evidenciate the location and extent of groundwater pollution.

For an integrated interpretation of the results in relation with the threshold values established in the legal regulations into force, the sensitive and less sensitive land use areas were delineated, taking into account the destination proposed in the urban areal plan. From the total area of approx. 124 ha of the analysed site, the land area that will have a sensitive use is of about 50 ha and the one with less sensitive land use about 74 ha. So as to determine the area considered as being significantly polluted interpolations of the data were done using SADA software. Thus the area determined is of 460000 mp (approx. 46 ha). Due to the fact that significant pollution was determined only in the surface layer (depth of max. 1 m), the total volume of contaminated soil is estimated at 460000 m<sup>3</sup>. However, since it can be reasonably assumed that the area located beneath the former buildings cannot be affected by significant pollution, the soil volume significantly polluted can be expected to be lower than presented previously, i.e. that volume was determined through a conservatory approach whereby all the land, including the areas covered by buildings, was similarly polluted.

Human health risk assessment was developed using a risk model developed by US EPA, using SADA software. Due to the fact that the analysed site it is not located in the vicinity of ecologically sensitive areas, and the future land uses do not imply such aspects, in this

application ecologic risk assessment was not developed. The future land use scenarios set for risk assessment were residential, industrial, recreational and excavations, and the potential exposure pathways – ingestion, inhalation and dermal contact. No unacceptable risks were registered for the elaborated assessments for none of the exposure pathways and none of the analysed land uses.

In what regards the risks associated to a potential home consume (for drinking) of groundwater, the risk assessment shows that would exist a total unacceptable risk for TPH (due to a potential vapour inhalation and water ingestion) as well as for manganese (in case of ingestion).

For the spatial delineation of the areas affected by contamination the SADA software was used. It could be seen that both in the sensitive land use areas as well as in those with less sensitive land use there are no areas to present a risk level higher than the threshold values and thus there is no contaminated land where to be imposed remediation actions.

In the last step, respectively of remediation, residual risk management and monitoring, based on the data resulted from the assessment of soil level contamination on the analysed site and using SADA software, it can be seen that the maximum calculated risk is below the acceptability limit, thus no remediation actions are required. The optimum level at which the reduction of residual risk will be done on the area determined as being significantly polluted will be established by negotiations between the regulatory authorities and the site owner, and will have a value between (level of acceptable risk) and 0,42 for the analysed case study.

The information received from the site developer show that the local authorities agreed the solution of applying remedial actions on an area of about 5000 m<sup>2</sup>, at this moment being under finalization the remediation technical project.

Taking into account the beneficial results of applying the methodology proposed in chapter 5 for the decision-making process, respectively the consensus between the site developer and the authorities based on the collected, investigated and analysed information, it is considered that this can be applied successfully on other similar sites.

## **CHAPTER 7. Comparative analysis of two decision support systems based on risk for the rehabilitation of contaminated sites: SADA and DESYRE applied on a case study**

### **7.2. Case study objectives**

Taking into account the previously presented aspects, the aim of this chapter is to present the results of a comparative application of the two DSSs on a case study, respectively the industrial site presented in chapter 6. This case study application will allow the comparative evaluation of the DSSs capabilities, equations, investigation areas, features, ease of use and

outcomes on the basis of the main steps of risk-based land management for contaminated sites. Out of the available risk-based DSSs, the two models chosen for the purpose of this paper were SADA and DESYRE. This was due to the fact that they have been used in a number of environmental modelling applications including site assessments, academic investigations, and regulatory frameworks designed to streamline characterization processes, being at the same time the subject of several peer reviewed articles dealing with different analyses in the area of decision making for contaminated sites rehabilitation.

According to the above considerations, the present comparison exercise represents an exchange of Euro-Atlantic, European-based and national experiences in the application of human health risk assessment models in the area of land contamination, aimed at the identification of relevant differences in input data needs, implemented equations and modelling concepts, and model applicability for the needs of stakeholders involved in the decision- making process.

## 7.8. Results and discussion

Due to the complex features and modules of the two DSSs, also based on the independent use of each module (either with separate data or based on results obtained in another module), it was decided to present the results obtained from their application in the case study as a sequence of modules. Based on this, the main features of the two DSSs applied to the case study are detailed and highlighted later.

### 7.8.1. Results

#### A. Risk assessment

As it was presented above, the human health risk assessment module was used with both DSSs and the Acceptable Concentrations (DESYRE) and Preliminary Remediation Goals (SADA) were obtained, respectively. The results are presented in Table 7.7.

Table 7.7. Acceptable Concentrations (mg/Kg) in DESYRE versus Preliminary Remediation Goals in SADA (Adults, Residential Scenario. C= carcinogenic, NC= non carcinogenic)

	Cd C	Cd NC	Cu	Ni C	Ni NC	Pb	Mn	TPH	Zn
<i>Residential Adult</i>									
<b>INHALATION</b>									
DESYRE		2E-01	1.83E+04		1.5E+00	1.60E+04	4.5E+00	1.62E+04	1.37E+05
SADA	1.80E+03	1.4E+04		1.20E+04	1.20E+05		6.90E+04	7.50E+03	
<b>INGESTION</b>									
DESYRE		3.6E+02	2.9E+04		1.4E+04	2.5E+03	1.02E+05	7.30E+04	2.19E+05
SADA		3.7E+02	2.9E+04		1.5E+04	2.6E+03	1.00E+05	7.30E+04	2.20E+05
<b>DERMAL CONTACT</b>									
DESYRE		6.88E+03	5.50E+04		2.75E+04	4.82E+03	1.92E+05	1.37E+04	4.13E+05
SADA		6.90E+03	5.50E+04		2.80E+04	4.80E+03	1.90E+05	1.40E+04	4.10E+05

TOTAL									
DESYRE		2E-01	9.36E+03		1.5E+00	1.51E+03	4.5E+00	6.76E+03	7.02E+04
SADA	1.80E+03	3.40E+02	1.90E+04	1.20E+04	8.90E+03	1.70E+03	3.40E+04	6.50E+03	1.40E+05

From the analysis of *Table 7.7*, it can be noticed that the results are similar in the case of the ingestion and dermal contact pathways, whereas significant differences were found for the inhalation pathway. These differences can be ascribed firstly to the fact that SADA uses Inhalation reference concentration (RfC) and unit slope factor (U/SF), while DESYRE uses Inhalation reference dose (RfD) and slope factor (SF), and secondly because of the different model equations used by the two DSSs for the inhalation pathway. While DESYRE applies the model equation used in ASTM (1998), SADA applies the equation proposed by US EPA (1996). The highest difference between these two concerns the estimation of the particulate emission factor value (PEF). In DESYRE this factor takes into account the extent of the contamination source in the wind direction, the site features and the particle emission rate (Pe) [mg/cm<sup>2</sup> s]. The latter depends on the rate between the average flux of the chemical species and its concentration on an area ~90.80 [g/m<sup>2</sup> s per kg/m<sup>3</sup>] (Q/C). In SADA the particulate emission factor value (PEF) (US EPA, 1996) takes into account, for example, the land surface roughness, the potential presence of a superficial layer that cannot be weathered and the presence of a vegetative cover. Overall, the fact can be distinguished that the value used in DESYRE is much more conservative than the one in SADA, and is up to the decision maker to choose the one which best suits the case study modelling).

As far as the results of the ingestion pathway for child receptors (according to the residential land use scenario) are concerned, the results obtained by the two DSSs were similar. Thus it can be said that both the softwares can be used for this purpose, whereas DESYRE has the advantage of including different exposure pathways such as dermal contact and inhalation (see *Tables 7.8.* and *7.9.*).

*Table 7.8. Acceptable Concentrations in DESYRE versus Preliminary Remediation Goals in SADA (Child, Residential Scenario, Ingestion Pathway). C= carcinogen, NC= non carcinogen (i.e. toxic)*

	Cd C	Cd NC	Cu	Ni C	Ni NC	Pb	Mn	TPH	Zn
<i>Residential Child</i>									
<b>INGESTION</b>									
DESYRE		3.90E+01	3.12E+03		1.56E+03	2.73E+02	1.09E+04	7.82E+03	2.34E+04
SADA		3.90E+01	3.10E+03		1.60E+03	2.70E+03	1.10E+04	7.80E+03	2.30E+04

Table 7.9. Acceptable concentrations in DESYRE versus Preliminary Remediation Goals in SADA (Child, Residential Scenario, Ingestion Pathway). C= carcinogen, NC= non carcinogen (i.e. toxic), CNC = carcinogen and non carcinogen

DESYRE, Residential, Child					
Substance	State	Ingestion	Dermal contact	Inhalation	Total
TPH	NC	7.82E+03	5.01E+03	1.61E+04	2.56E+03
Cd	CNC	3.9E+01	2.50E+03	1.1E+00	1.1E+00
Mn	NC	1.09E+04	7.01E+04	6.3E+00	6.3E+00
Ni	CNC	1.56E+03	1.00E+04	8.7E+00	8.7E+00
Pb	NC	2.73E+02	1.75E+03	2.20E+04	2.34E+02
Cu	NC	3.12E+03	2.00E+04	2.52E+04	2.44E+03
Zn	NC	2.34E+04	1.50E+05	1.89E+05	1.83E+04

As both DSSs involve spatial assessment, the total risk maps were drawn in order to have a more clear view of the results of the different approaches. Thus *Figure 7.3.* shows that SADA has a less conservative approach for risk assessment due to the differences presented previously for the Inhalation Pathway model equation.

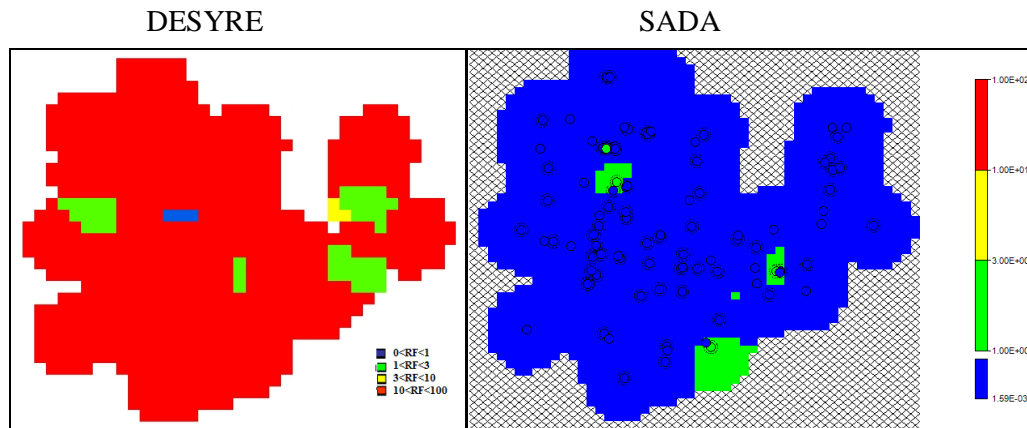


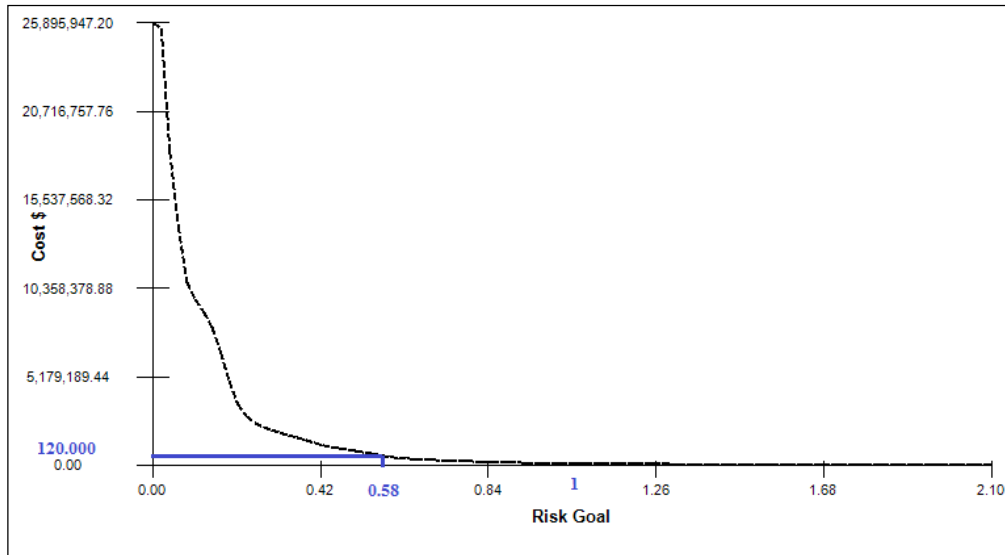
Figure 7.3. Spatial maps representing the total Risk Factor for DESYRE and the total risk for SADA according to the Residential scenario and the Adults receptors.

Note: Similar colors represent similar classes of risk.

#### B. Remediation technology evaluation to support the decision-making process

According to the results of the human health risk assessment, and on the basis of the Inverse Distance geospatial model used for the spatial estimation of the risk, the cost/benefit analysis in SADA was also applied. For each of the contaminants of concern as well as for pooled data (separately for carcinogenic and non-carcinogenic substances), an area of concern

was defined and afterwards a cost/benefit analysis was performed based on cost vs cleanup interview (*Figure 7.4*).



*Figure 7.4. Cost/benefit analysis result from SADA*

Analyzing the results of the cost- benefit graph for the case study, it can be seen that applying remedial actions aimed at reducing the residual risk levels leads to an exponential rise of costs. The calculated costs for the remediation of areas affected by significant pollution, involving the treatment of a soil volume of 460,000 m<sup>3</sup>, are six times higher than those for the reduction of the residual risk to the acceptability limit (*Figure 7.4.*). Thus, it would result in the reduction of the risk level to a hazard index of 0.58, which represents a tolerable risk, well below the risk limit considered to be unacceptable. It can be considered that reduction of risks below level 1 on the hazard index is an acceptable benefit and represents the minimum and mandatory remediation work level.

As far as the DESYRE remediation technology modules are concerned, the application of the first filter selected the seven technologies reported in *Table 7.10*. from the remediation technology database for soil. The second filter was then applied in order to select those technologies which are shown to be suitable for the case study on the basis of the site's hydrogeological characteristics. The score associated with each selected technology by Multi-Criteria Analysis (Critto et al., 2007) is reported in *Table 7.10*.

Table 7.10. Remediation technology selection and ranking obtained by DESYRE

No. Crt.	Remediation Technology	Remediation technology ranking: Fuels	Remediation technology ranking: Inorganics
1	Enhanced bioremediation	3.404	
2	Soil vapour extraction in situ	3.599	
3	Biopile	2.620	
4	Separation	2.484	
5	Soil washing	3.138	3.265
6	Landfill cap	1.756	1.819
7	Electrokinetic separation		3.206

The user can simulate the remediation technology applications, which lead to the reduction of contaminant concentrations in the analyzed media on the basis of the performance of the specific remediation treatments. The maps of the residual concentrations after remediation is an input to the Residual Risk Assessment module which provides the estimation of the residual risk after the remediation and the estimation of the associated uncertainty through the use of Monte Carlo probabilistic analysis (Carlon et al., 2008).

Since SADA does not provide any functionality related to the selection of the best remediation technologies and the creation of different remediation scenarios, the comparison cannot be provided and the presentation of the DESYRE results is beyond the scope of this paper. Thus it can be observed the fact that the two DSS have complementary modules that can be used based on the necessities of the site-specific remedial project.

## 7.9. Conclusions

The overall primary conclusion that can be drawn from the comparative exercise is that both DSSs can be profitably used to support the contaminated site decision-making process, with both systems leading to similar conclusions which are mainly dependent on the risk assessment results. However, depending on the users' specific objectives and their needs in the contaminated site remediation process, one or other of the two DSSs could provide the more effective support.

On the other hand, a suitable combination of their respective modules and functionalities could lead to the most efficient assessment since such an integration can effectively cover all the necessary phases, namely from the development of a site-specific sampling plan to the selection and evaluation of the best remediation technologies to be applied to the site, or various parts of it. This effectively answers the starting point question for the exercise: "Does a comparison of the two DSSs features support the stakeholder in deciding which is more appropriate and best suits their decision-making needs?".

The respective risk-assessment modules of the two DSSs were shown to provide similar results, with the primary differences resulting from the subjectivity used in the selection of input parameters. In this regard, it is important to stress that these differences need to be clearly understood and accepted by the stakeholders involved in the decision-making process, and that

the appropriateness of all parameters to the issues under consideration needs to be demonstrated. On the other hand the exercise demonstrated that, while DESYRE uses site-specific fate and transport models and SADA uses default transport coefficients, the final risk assessment results are comparable.

The comparison exercise also showed that, in terms of the main goal of the study, the two DSSs can have different roles. Using SADA the stakeholder can develop an initial sampling plan in case the site has not yet been investigated, and/or the development of a secondary sampling plan in order to help define the residual hazards and risks. In contrast, by using DESYRE the stakeholder can, through the socio-economical module, determine a potential future land use, in case this is not yet determined.

SADA, through its greater accessibility, has the advantage of being used by a larger number of stakeholders during the decision-making process. Moreover as a final decision-making point SADA estimates the areas of concern and develops the cost/benefit analysis in order to support the stakeholder in determining suitable actions, and their costs, based on the level of risk. On the other hand, DESYRE can perform the selection and application of the most suitable remediation technologies and the evaluation and comparison of different remediation scenarios.

In drawing these conclusion we recognize that SADA was analysed in more detail than DESYRE in regard to several environmental modelling applications including site assessments, academic investigations, and regulatory frameworks designed to streamline characterization processes. In addition, SADA has been the subject of several peer-reviewed articles dealing with different analyses in the area of decision-making for contaminated sites rehabilitation. Nonetheless, we consider that this paper helps enhance the knowledge of its capacities.

Overall, we consider that both of the DSSs examined, each of which forms key linkages between factual data/information and professional value judgements, will provide important support for the stakeholders involved in decision-making concerning the effective management of risks from contaminated brownfield sites.

## **CHAPTER 8. Conclusions, original contributions and future work**

### **8.1. Conclusions**

The present thesis started from the premise according to which at international level it is estimated that potentially polluting activities are developed on millions of industrial sites, of which only a small part benefited from investigation and assessment actions for the level of pollution so as to determine the areas that need remediation. At the same time, taking into account the fact that at Romanian level the period of privatization was later than in other West European countries, reason why also the management of contaminated sites became a necessity

and priority later than for these, the needs and potential of development of the field being high. The scope of the thesis was to elaborate at Romanian level, a methodology for the management of industrial sites historically contaminated based on land-use planning and risk assessment and its validation by implementing it on a case study (the former industrial site S.C. Tractorul Braşov S.A.).

The main conclusions of the thesis can be differentiated in two categories, namely a category of conclusions based on the critical analysis and integrated of the situation in the field of industrial sites historically contaminated in USA, EU and Romania, including by developing a sociological survey based on a questionnaire to establish the awareness of stakeholders in Romania (category finalized by setting a list of proposal to improve the field at national level), and respectively a second category of conclusions, that could partially be integrated with the first one, respectively conclusions based on the elaboration, implementation and validation of the methodology proposal in the thesis on a case study, as well as the comparative analysis of applying and the results obtained with two decision support systems. Thus, in the first category of conclusions can be included more development proposals for the field of industrial sites historically contaminated management at national level, respectively:

- elaboration, implementing and maintaining some management and operational procedures regarding contaminated/potentially contaminated sites management for the authorities in the field, which to include provisions regarding quality, environment and/or information security management (establish the procedures to collect, process, validate, storage and upgrade the data; identification of data/information sources; establishment of collaboration modalities with institutions that hold data/information regarding soil and subsoil quality, as well as of the manner of disseminating the information to the public in a structured and identical way;
- continuous upgrading of the data regarding contaminated sites inventory; reissue of the national inventory questionnaire by the Ministry of Environment and Forests, setting of a filling-in shedule and transmission to site owners;
- the need to upgrade the legislation in the field, based on the existent regulations and the developments at international level; setting clear definitions for chey concepts, so as to omit any interpretations; the need to issue several guidelines/technical documents regarding the inventory, investigation, risk assessment, remediation and post-remedial monitoring of historically contaminated sites;
- upgrade of the threshold values regarding land investigation, these being issued since 1997; these criteria should be established taking into account both land-use planning and risk assessment aspects (source-pathway-receptor analysis); the adaptation and application of new rehabilitation standards should combine both;
- human health and ecologic risk assessment methodologies should be clearly defined, detailed and eventually adapted to the ones used internationally;
- detailed specification of the methodological parameters needed for risk assessment (physical, chemical, hydrogeological, climate, toxicological, exposure parameters);

- dissemination of courses and/or trainings in the field for stakeholders involved in the decision-making process;
- elaboration of a geochemical atlas, similar to the one developed for Iasi and surroundings (Iancu și Buzgar, 2008), respectively Heredea, (2011) for the three regions, respectively the analysis developed by Dumitru et. al., 2011;
- the regional analysis of industrial sites historically contaminated by elaborating based on the data in CoSis database (or on the reports of ANPM, ARPM, APM) of several maps with the distribution of the inventoried sites; eventually after this, of a regional risk assessment.

In the second category of conclusions, based on the aspects developed in the thesis, the following issues can be included:

- taking into account the relatively short period of time since the development of this field started at national level, as well as the previously identified lacks, it is considered that the proposal of methodology in the thesis for the management of industrial sites historically contaminated based on risk assessment and land-use planning is relevant and efficient for the time being;
- taking into account the beneficial results of applying the methodology proposed for the decision-making process, respectively the consensus between the site developer and the authorities based on the collected, investigated and analysed information, it is considered that this can be applied successfully on other similar sites.

## **8.2. Original contributions**

Based on the research in this thesis, the following original contributions can be highlighted, namely:

- The elaboration of a literature review regarding the concepts of risk and hazard used in literature, mainly for the field of historically contaminated sites management;
- The detailed presentation of risk assessment and management concepts for environmental field in general, and contaminated sites, in particular (approached relatively recently in the national literature and legislation);
- The comparative analysis of the legislative situation at USA, EU and Romanian level, highlighting the lacks existent at national level;
- The critical analysis of the inventory for contaminated sites in Romania, for the period 2006-2011;
- Setting recommendations regarding the revision and development of the legislative framework currently existent at national level, based on the previously identified aspects, as well as the elaboration of several atlases, support studies etc.;
- Highlighting and assessment of the aspects related to the need of a conceptual site model in the investigation and analysis of contaminated sites;

- The comparative analysis of the issues related to land-use planning at European level from the national situation, for the management of contaminated sites, and the proposal of categories based on risk criteria for land-use set for national level;
- The detailed description of the concept of risk assessment, focusing on the use and applicative features of site specific risk assessment (human health and ecologic risk assessment), of regional risk assessment, of the potential uncertainties of these analyses, as well as of the decision support systems of the decision-making process for the management of contaminated sites, presenting details regarding the use of SADA and DESYRE DSS;
- Presentation and integration of the decisional approaches used in historically contaminated sites management for the proposal of methodology in the thesis;
- The analysis of the main stakeholders involved in the industrial sites historically contaminated, and their role;
- Development, dissemination and statistical and applicative analysis of a sociological survey based on a questionnaire, so as to support the development of the methodology proposed in the thesis;
- The development of the methodology proposal for the management of industrial sites historically contaminated based on risk assessment and land-use planning;
- Application of the previously proposed methodology on a case study, namely the site of a former industrial platform S.C. Tractorul UTB Braşov S.A.,
  - The exact characterisation of the studied area, based on a theoretical material of well known authors and information in the archives existent on the site, so as to detail as much as possible the reality of the area proposed for study;
  - The analysis of the previous environmental studies for the precincts of the site;
  - Setting the potential pollution sources for the analysed site;
  - Statistical analysis of the data resulted from the chemical analysis for soil and groundwater, for the period 2008-2009;
  - Assessment of results for soil and groundwater in comparison with the threshold values in the legislation;
  - Determination of the geological profile and of groundwater flow direction;
  - Human health risk assessment using only the values determined as being certain based on the statistical analysis;
  - Development of a cost/benefit analysis for the results of human health risk assessment;
  - Suggesting recommendations for remedial works and reuse of the land for the case study;

- Comparative analysis of two decision support systems based on risk for the rehabilitation of contaminated sites: SADA and DESYRE applied on a case study;
- Classification of the two DSS based on categories in literature;
- Comparative analysis of the two DSS modules and of the results obtained by applying similar modules;
- SWOT analysis to highlight the utility of applying a DSS for the analysis of an industrial site historically contaminated, during different steps of the decision-making process and by different stakeholders involved in the management.

All these contributions that issue aspects of originality were the result of collecting, systemating, processing and afterwards analyzing and interpreting a vast documentary material. These theoretical steps could not find their scientific finality without being doubled in parallel by the concrete field study, which indirectly supported identification of previously presented solutions.

The personal contributions meant to complete the ample previous papers on this theme where themselves a scope of this thesis and are considered a benefit and a plus brought for the previous studies, which are few. This even more as it was tried the development of a connection between the existent theories that deal with the management of industrial sites historically contaminated, and the use of concepts of risk assessment and land-use planning.

Nevertheless, the thesis can represent a useful instrument for the decision factors, integrated or not institutionally, to offer support for decision-making regarding the management of industrial sites historically contaminated, at Romanian level. The thesis respects both the principles and rules of a scientific paper, but, as much as possible, it was adapted to a easy understandable language that can be read by the general public, interested in such issues. As it was already mentioned, the theme of the thesis will be even more interesting as the decision-making process and the management of industrial sites historically contaminated are themes more and more discussed in such studies, both at international and national level.

It also has to be mentioned the fact that having no claim of a complete study for the subject, treating this theme from the point of view of the concrete gathered data, as well as using adjacent disciplines, was done very attentively, letting at the same time new research subjects in the perspective of future works.

### **8.3. Future work**

Taking into account the inchoate level of development for this field at international level, and mostly national, it is considered that the potential for future works is high.

Based on the literature review regarding the hazard and risk terms used mainly in the field of industrial sites historically contaminated management, as well as on the detailed presentation of risk assessment and management in the environmental field generally, and contaminated sites field particularly (approached relatively recently in the national legislation

and literature), and also through the comparative analysis of the legislative situation in USA, EU and Romania, highlighting the lacks existent at national level, all these being developed in the current work, it can be supported the development of the national legal framework. At the same time, following the critical analysis for the situation of the national inventory for contaminated sites in Romania, for the period between 2006-2011, recommendations were proposed for the development of the field at national level, respectively it is considered useful the revision and development of the national legislative framework, taking into account the proposals of the current work.

In what regards the reuse of industrial sites historically contaminated, the aspects concerning land-use planning is an important issue. In the thesis were proposed categories based on risk criteria for the land-uses set at national level, thus a future development based on this proposal, could be the spatial representation of the proposed land-uses by land-use plans set by the authorities at regional level, and later their comparison with regional spatial representations for the areas affected by different pollution types.

At legislative level technical guidelines can be issued to develop the risk assessment notions, respectively for the site specific assessment (human health risk assessment and ecologic risk assessment) and for regional risk assessment; models, equations, necessary parameters (determined on site specificity, or for exposure, based on parameter types) the potential uncertainties of these analyses, as well as information regarding the decision support systems for the decision making process in case of contaminated sites management.

By evaluating the results of the sociological survey based on a questionnaire it could be observed the fact that the development of the field is desired by all the stakeholders involved in contaminated sites management, thus as a future development it is considered to be useful the revision of the necessities evoked by the stakeholders, in accordance with several criteria.

The practical applications case study support the development of the field and thus the one developed in the current thesis taking into account the proposed methodology had efficient results, and so further on it could be developed and adapted based on the needs and suggestions of the previously mentioned stakeholders.

A major development in the field could be the development of a decision support system for the industrial sites historically contaminated, to support the methodology based on risk assessment and land-use planning, to integrate site specific aspects, as well as regional features, but which to include determined parameters, specific to the site, respectively for the region.

Nonetheless, based on the results obtained in the current thesis, as well as based on the author's expertise, potential future developments could be research project proposals in the field.

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#### **6. Other publications**

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