Environment International 35 (2009) 202–213

Contents lists available at ScienceDirect

Environment International

journal homepage: www.elsevier.com/locate/envint

Review article

A review of regulatory decisions for environmental protection: Part I — Challenges in the implementation of national soil policies

S.M. Rodrigues [a,*], M.E. Pereira [a], E. Ferreira da Silva [b], A.S. Hursthouse [c], A.C. Duarte [a]

[a] Centre for Environmental and Marine Studies (CESAM)/ Department of Chemistry, Universidade de Aveiro, 3810-193 Aveiro, Portugal
[b] GeoBioTec — GeoBiosciences, Technologies and Engineering, Department of Geosciences, Universidade de Aveiro, 3810-193 Aveiro, Portugal
[c] University of West Scotland, School of Engineering & Science, Paisley Campus, Paisley, PA1 2BE, Scotland, UK

ARTICLE INFO

Available online 24 September 2008

Keywords:
Contaminated land management
EU environmental policies for soil protection
Risk assessment
D–P–S–I–R approach

ABSTRACT

Since many soil studies have already revealed the possible risks to human health and the environment arising from contaminated soils it is therefore crucial to preserve soil quality under current and future conditions. In the last three decades a number of countries already introduced national policies and practices for the management of contaminated sites, and in 2002, an EU Thematic Strategy for Soil Protection was proposed by the European Commission.

In this paper we review and analyse several national contaminated land policy regimes already in place in order to assess common elements and to identify specific needs in the development of national soil policies. We propose a framework that combines the D–P–S–I–R structure of policy evaluation with the Source–Pathway–Receptor approach to health risk assessment to support the development of effective country specific regulatory decisions for managing contaminated land in countries where these are yet to be implemented. The framework proposed allows decision makers to effectively use available information and to identify existing data gaps. As a result it is apparent that while there are technical aspects of site characterisation, risk assessment and remediation processes that could be commonly implemented at an EU level there are certain trans-scientific aspects that require political choices and need to be customized by EU Member States.

Contents

1. Introduction

Pressures posed over the soil resource are associated with irreversible land losses worldwide. Unsustainable development results in the production of brownfields and derelict land (Simpson, 1996). Rising degradation problems are increasingly affecting the sustainability

* Corresponding author. Tel.: +35 1234370737; fax: +35 1234370084.
E-mail address: smorais@ua.pt (S.M. Rodrigues).

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doi:10.1016/j.envint.2008.08.007

of the soil resource and its ability to support life systems (Plant et al., 2001). The main drivers are population pressures, usually concentrating in localised areas, and changes in climate and land use. Soil contamination has been identified as one of the major threats to soil function in Europe by the Communication from the European Commission "Towards a Thematic Strategy for Soil Protection" (EC, 2002).

Overall estimates from the European Environment Agency (EEA) identify metals and mineral oil as the main soil contaminants in Europe. Metals (~37%), mineral oil (~34%), PAHs (~13%), and aromatic hydrocarbons (benzene, toluene, ethylbenzene, and xylene–BTEX, ~6%) affect almost 90% of the European sites for which information on contaminants is available, while their relative contribution may vary greatly from country to country (EEA, 2007). Contaminated sites identified in Europe are predominantly associated with local sources deriving, in decreasing order, from industrial production and commercial services, municipal waste treatment and disposal, the oil industry (extraction and transport) and industrial waste disposal (EEA, 2007).

Soil contamination may have important consequences in terms of soils' ability to function. Soils may fail to support vegetation and biomass production, may fail to provide valuable materials and substrate to human activities, ecological systems and biological cycling of nutrients or may be unable to act as filter and buffer, affecting the hydrosphere, compromising groundwater resources and threatening aquatic ecosystems (van Straalen, 2002; Scullion, 2006). In cases of severe contamination and where risks to human health and/ or the environment are observed, soil remediation is necessary. Johnson (1999) when referring to hazardous wastes sites stated that environmental remediation is the best long-term solution to the prevention of adverse reproductive effects from exposure to hazardous substances released from such sites. Although annual expenditure on clean-up in the EU Member States for the period 1999–2002 have reached € 35 per capita per year in some countries and that a substantial sum of money has already been spent on soil remediation in Europe, this is still relatively small (up to 8%) when compared with the estimated total costs (EEA, 2007). Soil contamination particularly from historical activities, still remains a problem despite several national and international initiatives that have been established to remediate contaminated sites and to reduce the release of contaminants into the environment: licence conditions for the operation of industrial processes; control on the application of sewage sludge to land; control on the spreading of biosolids to land; and, the landfill of waste.

Strategies to deal with soil contamination are being developed through a variety of regulatory systems. During the last 20 to 30 years, soil protection policies have been developed and implemented in a stepwise manner, both nationally (particularly in the UK, The Netherlands and Germany) and at the EU level. Plans for the introduction of measures and requirements for EU Member States to prevent new and remediate historical soil contamination include the development of inventories of contaminated sites and the definition of targets for prioritisation of remediation actions. These plans are expected to have important consequences for soil management practice and national soil policies across Europe.

In this work, we present an analysis of the evolution of soil contamination management through time and we review several regulatory frameworks for contaminated land management, based on past practice and future demands. We also propose and describe a framework that combines the D–P–S–I–R structure of policy evaluation with the Source–Pathway–Receptor approach to health risk assessment to support the development of effective country specific regulatory decisions for managing contaminated land in countries where these are yet to be implemented.

2. Soil science: evolution of soil quality assessment through time

Historically, the concept of soil quality has been intrinsically associated with the limitations or suitability of a soil for a certain use (Seybold et al., 1997). First discussions on soil quality were driven mostly by agricultural needs and the suitability of soil as crop growth substrate (Karlen et al., 2003). Although the definition of soil quality has changed and been adapted through time, it is clear that soil quality is linked to the concepts of "fitness for use", "capacity" and "function" (Seybold et al., 1997). Karlen et al. (1997), defined soil quality as the "capacity of a soil to function within the ecosystem boundaries to sustain plant and animal productivity, maintain or enhance water and air quality and support human health and habitation", or, in simple terms, quality is the capacity of soil to function. This concept balances multiple soil functions and is strongly linked to the role of soil within the ecosystem and dependent on the interactions with other components such as biota, air, or water quality and human health.

According to van Straalen (2002), soil contamination can also be assessed both from a structural and a functional perspective. Moreover, the influence of contamination on the ability of soil to function (e.g. as a habitat for biota or a substrate for vegetation) and thereafter on soil quality has been acknowledged (Belotti, 1998; Scullion, 2006).

In the last three decades, numerous assessments of soil contamination and pollution have been conducted and focused on different contaminants, different land uses and on varied contamination sources, as for example mining and industrial activities, agricultural practices, or oil spills (see for example recent studies by Chung et al., 2007; Douay et al., 2007; Iturbe et al., 2007; Kim et al., 2007; Liao et al., 2007; Masaka and Muunganirwa, 2007; Nganje et al., 2007; Schulin et al., 2007). Further issues of concern such as the analysis of processes occurring in soils (speciation, oxidation/reduction, solubility/precipitation, transport/mobility, sorption phenomena, and bioavailability/ toxicity) in support of the characterisation of contaminated sites have also been subject of study (e.g. Hamon et al., 1998; Dowdle and Oremland, 1998; Hursthouse, 2001; Smolders et al., 2004). In addition, other authors have focused on the analysis of environmental toxicity of contaminated soils and on the assessment of risks to terrestrial ecosystems and human health from contaminated land (Theelen, 1997; Nathanail, 2006; Smith et al., 2006a; Bennett et al., 2007; Leitgib et al., 2007).

Although the study of particular contaminants, contamination incidents or areas of land degradation provide valuable generic information on the accumulation of chemical elements and/or compounds this is sometimes insufficient for comprehensive environmental change analysis or soil function evaluations since soil is a highly complex media interacting with other environmental compartments (Plant et al., 2001; Scullion, 2006). To effectively integrate soil function into contaminated land management three major components must be considered: biological productivity, environmental quality, plant and human health. A recent review of soil monitoring systems in Europe (Morvan et al., 2008) has highlighted the requirements for harmonisation of existing soil monitoring networks as well as the needs for additional monitoring sites and cross-method validation.

3. Soil policy: developing regulatory frameworks for the management of contaminated sites

3.1. Actions at an EU level

Soil protection has not, to date, been subject to a specific legislative instrument at EU level. References to soil protection can be found scattered throughout the European Community regulatory structure, establishing a number of instruments and measures that have a direct or indirect impact on the quality of soil. A number of aspects directly or indirectly related to soil contamination and/or remediation issues are addressed by waste, water, chemical, impact assessment, environmental liability, and air quality policies. Table 1 indicates the EU policy measures and instruments that explicitly (directly) address aspects of soil contamination and the legislation that may have some indirect effects on soil contamination. A distinction between local and diffuse soil

Table 1
Main EU environmental policies that address soil contamination aspects

EU environmental policies		Diffuse soil contamination aspects		Local soil contamination aspects	
		Addressed			
		Directly	Indirectly	Directly	Indirectly
Waste	Waste Framework Directive (2006/12/EC, codified version of Directive 75/442/EEC as amended)				√
	Directive 91/689/EEC on Hazardous Waste, amended in 1994				√
	Directive on the Disposal of Waste Oils (75/439/EEC amended in 2000)				√
	Landfill Directive (1999/31/EC)				√
	Sewage Sludge Directive (86/278/EEC)	√			
	Directive2006/21/EC on the management of waste from the extractive industries	√		√	
Water	Water Framework Directive (2000/60/EC)	√			
	Nitrates Directive (91/676/EEC)	√			
	Urban Wastewater Treatment Directive (91/271/EEC)		√		
	Bathing Water Directive (2006/7/EC)		√		
Air	Air Quality Framework Directive (96/62/EC) and its Daughter Directives		√		
	Directive on National Emissions Ceilings (2001/81/EC)		√		
	Directive on Integrated Pollution Prevention and Control (96/61/EC)	√			
	Directive on Large Combustion Plants (LCPD) (2001/80/EC)		√		
Chemicals	Thematic strategy on the sustainable use of pesticides	√			
	Directive on Biocidal Products (98/8/EC)62	√			
	Directive 91/414/EEC on plant protection products	√			
Impact assessment	Environmental Impact Assessment Directive (85/337/EEC amended in 1997 and 2003)	√		√	
	Strategic Environmental Assessment Directive (SEA) (2001/42/EC)	√			
Environmental liability	Directive 2004/35/EC on environmental liability with regard to the prevention and remedying of environmental damage			√	

contamination sources has been made to allow a better understanding of the potential impact of these instruments on the abatement of soil contamination. Most of these instruments are designed to control and/or prevent emissions at source, reducing the influx of contaminants into the environment and in this way mitigating the impacts of the accumulation of contaminants on different environmental compartments such as the soil compartment. These measures address different types of elements and substances such as metals, acidifying and eutrophying compounds, nutrients, pesticides and other organic compounds. The Waste Framework Directive (2006/12/EC) that sets provisions for waste disposal and recovery and for regulating the recycle and re-use of contaminated wastes may indirectly contribute for a more sustainable remediation of contaminated sites and for the prevention of soil contamination. The implementation of the Water Framework Directive (2000/60/EC) towards a good status of water resources may directly lead to the recovery of contaminated areas and to the mitigation of certain soil contamination problems. Due to the strong interdependencies between groundwater and soil systems the implementation of the Groundwater Directive (Directive 2006/118/EC on protection of groundwater against pollution and deterioration (EC, 2006a)) is also expected to have a direct impact on soil quality. This legislation includes provisions aimed at preventing and limiting indirect discharges (after percolation through soil or subsoil) of pollutants into groundwater. Although not dealing with historical contamination problems the Environmental Liability Directive (2004/35/EC) already includes provisions for addressing new contamination problems and for the remediation of land damage whenever there is risk associated with contaminated land and where this contamination may adversely affect human health. According to the Environmental Liability Directive, remedial measures must be function oriented and take into account harmful substances, preparations, organisms or micro-organisms, their risk and the possibility of their dispersion. Certain instruments such as the REACH regulation (Registration, Evaluation, Authorisation and Restriction of Chemical substances), the Common Agricultural Policy, Internal Market regulations on product quality and biodiversity conservation policies also address in a direct or indirect way the problems related to soil contamination. So far, historically contaminated land within the EU has been dealt with mostly through market driven re-development or specific public driven projects.

Although diverse, the EU instruments and measures directly addressing soil issues are somewhat fragmentary. These policies (that are not primarily oriented towards soil protection) focus mostly on diffuse rather than local contamination aspects and they are quite limited when dealing with historical contamination and site development issues.

Since knowledge of soil-related problems is increasing in the EU (Thornton et al., 2007), a Thematic Strategy on Soil Protection was launched in 2002 (EC, 2002, 2006b) which explicitly recognized the importance of preventing soil degradation. Considering that soil is a resource of common interest within the European Community, that the degradation of the soil resource may have transboundary effects and/or affect other resources of common interest (such as water and biodiversity), that soil contamination may affect food and feed crops that are being freely traded within the internal market and therefore pose a risk to human and animal health and that the implementation of very diverging contaminated land management regimes within the EU may lead to distortions of competition within the internal market (EC, 2006c), the Commission recognized the need to enact framework legislation with the principal aim of protecting the soil resource and promoting its sustainable use. Therefore, in 2006 a new legislative proposal — a draft Soil Framework Directive, SFD (EC, 2006c) was presented by the European Commission. The draft SFD is the statutory elaboration of the Thematic Strategy which takes into account seven large-scale threats to European soils (contamination, erosion, loss of organic matter, compaction, salinization, soil sealing and landslides) and aims to prevent soil degradation, based on the following principles: integration of soil concerns into other policies, prevention of threats to soil and mitigation of their effects, preservation of soil functions within the context of sustainable use, and the remediation of degraded soils. It allows local soil and land use to be taken into account and includes the possibility to delegate the enactment of policy aims and measures to local authorities. Concerning contaminated land, the SFD (as proposed in 2006) includes a systematic inventory of contaminated sites, the definition of National Remediation Strategies and a soil status report to be made available to competent authorities whenever a site on which a potentially polluting activity has been developed, is to be sold. The Commission aims to develop grounds for a common risk-based strategy to manage historical contamination based on a step by step approach that includes the collection of the information on the full extent of site contamination problems in all Member States, on the evaluation of associated risks and on the prioritisation of remediation needs. The draft SFD demands a precautionary approach to be followed and defines a list of potential sources of soil contamination, such as industrial facilities, mines and waste landfills both operating and after closure, former military sites, ports and airports, dry cleaners and waste water treatment installations and considers a broad group of dangerous substances for which future soil contamination must be prevented and past contamination must be remediated (EC, 2006c). According to the draft SFD, contamination that would "hamper soil function or give rise to significant risks to human health or the environment" is to be prevented (EC, 2006c). Sites are considered contaminated and needing remediation whenever "they pose a significant risk to human health or the environment", but the mechanisms through which "significant risk" is assessed are yet to be defined. In the Impact Assessment document associated with the implementation of the Thematic Strategy the Commission estimates that 3.5 million potentially contaminated sites exist in Europe, with 0.5 million sites needing remediation (EC, 2006d). Insofar as it can be estimated the costs associated with soil contamination vary between € 2.4 and 17.3 billion per year, but other estimations indicate that these costs could amount annually to up to € 208 billion (EC, 2006d). Additional European wide data is needed to support an effective estimation of the costs associated with contamination problems, and of the costs and benefits of the implementation of the SFD in each Member State. Relevant costs for Member States may include those associated to the systematic identification of contaminated sites and their remediation, possible land values depreciation or land use restrictions. Relevant benefits are: the reduction of risks to human health for people living in the surroundings of contaminated sites or at risk of drinking potentially contaminated water; the reduction of surface and groundwater contamination; the reduction of environmental impacts and ecological risks; the reduction of losses of biodiversity and soil fertility; the benefits from recycling and re-use of materials; and the potential land value appreciation after site remediation. Moreover, given the wide range of national situations across the EU (some countries have national soil policies in place since the early 1980s, others have yet to introduce contaminated land management regulations and to start the development of a national policy), Member States are still to explore the alternatives for the implementation of the Thematic Strategy and its relation with the national approaches already developed (Bouma and Droogers, 2007). To achieve the EU soil protection objectives will require rational land use planning at national, regional and local levels that allows soil's capacity to be taken into account (Thornton et al., 2007).

The enactment of EU soil framework legislation is also associated with further harmonised research needs particularly on scientific and technical aspects of risk assessment and remediation solutions. An analysis of future research needs for Europe in support of the European Thematic Strategy for Soil Protection has been developed by Blum et al. (2004). These authors highlight the pressing need for research which combines the analysis of processes related to threats to soil (such as contamination) and the development and harmonisation of methods for soil monitoring. Despite relevant subsidiarity aspects that are crucial for the effective implementation of a flexible EU framework, the harmonisation of scientific aspects of contaminated land risk assessment will also require further discussion (Carlon, 2007; Vegter, 2008). The integration of soil function analysis into site development practices as well as the definition of relationships between site clean-up and restoration of soil functions will require intensified contaminated soil research which can be rationally integrated with soil policy to allow the development of robust science-based regulatory decisions for contaminated land management. In addition, the overall effects of soil function restoration on climate and on other environmental compartments need further evaluation.

3.2. Other European concerted actions

Several international organisations and concerted actions have committed to the analysis of practical approaches for the prevention and remediation of contaminated soil. A few examples will be described next. The EU project CARACAS (1995–1998), Concerted Action for Risk Assessment for Contaminated Sites in Europe, focused on the evaluation of the practical state-of-the-art of contaminated land investigation and risk assessment practices in European countries. The CARACAS project closed in 1998 and its work was incorporated into CLARINET (1998–2001), the Contaminated Land Rehabilitation Network for Environmental Technologies in Europe (http://www.clarinet.at), which developed the concept of Risk Based Land Management (RBLM) as a step forward towards an integration of sustainable soil quality, protection of water and land use management in environmental policy. Another example of stakeholders' initiatives is the network NICOLE (Network for Industrially Contaminated Land in Europe, http://www.nicole.org) that is an independently funded European forum set up in 1995 where industry, service providers and academia cooperate to drive forward practical issues to contaminated land management. The link between contaminated land policies and spatial planning also provided opportunities to use (re)-development processes as drivers for improving soil quality and to developing approaches for sustainable brownfield redevelopment and revitalisation. These aspects have been dealt with for example by CABERNET, the Concerted Action on Brownfield and Economic Regeneration Network (http://www.cabernet.org.uk) that aims to enhance the rehabilitation of brownfield sites by addressing the complex multi-stakeholder issues that are raised by brownfileld regeneration. CABERNET was established in January 2002 and builds on the work of the previous network CLARINET. The development of public–private partnerships and the re-use of marketing concepts in the context of brownfield regeneration have been analysed by the project REVIT (2003–2007), Revitalising Industrial Sites (http://www.revitnweurope.org). The HERACLES (Human and Ecological Risk Assessment for Contaminated Land in Europe) expert network is an initiative of the European Commission, DG Joint Research Centre (*JRC*) is a long term research framework for the collaboration of the JRC with other European institutes (research institutes and other interested bodies) in developing common references for risk assessment of contaminated land in Europe (Swartjes and Carlon, 2008). In the framework of the HERACLES network, a review of derivation methods for soil screening values in Europe ("Derivation methods of soil screening values in Europe: a review and evaluation of national procedures towards harmonisation") has been published (Carlon, 2007). This review analyses the basis of screening values used in EU Member States and initiates a discussion on the reasons for their differences and on the scope for harmonisation.

In addition, INTERREG projects (funded under the European Regional Development Fund) and projects funded by R&D EU programmes have focused on integration aspects of contaminated land management and soil protection (Prokop, 2005). These actions have provided an important opportunity for the exchange of knowledge on contaminated soil management and a relevant underpinning of international cooperation on scientific and technical issues. International discussions on risk assessment practices and on the development of the RBML approach have been a useful step to increase the flexibility of contaminated land management national regulations in Europe and for the development and implementation of site-specific risk assessment practices. International discussions on the links between soil protection and spatial planning, on multi-stakeholders participation and on the development of innovative financing schemes for brownfields regeneration allow a common understanding to be reached. They also provide an integrated information base, drawn from experiences across Europe, to support re-development projects that create opportunities for dealing with historically contaminated sites in European urban areas in a more sustainable manner. Science-based discussions on the development of European common references for soil quality assessment are also crucial for the implementation of future EU framework soil legislation.

3.3. Actions at a national level

3.3.1. European countries

Although requirements for soil protection are generally included in several national legislative acts (e.g. environmental framework legislation; water, waste and mining regulations), some countries have already developed national policies for the management of contaminated sites or specific legislation regulating investigation and clean-up of contaminated land. Reviews of national soil policies from different perspectives can be found in literature (Ferguson, 1999; de Sousa, 2001; Van Veen, 2002; Prokop, 2005; Provoost et al., 2006; Smith et al., 2006a; D'Aprile et al., 2007; Thornton et al., 2007; Bergius and Oberg, 2007; Bouma and Droogers, 2007; Carlon, 2007). These authors analyse soil policies from different countries in an international context, discussing issues such as legal frameworks, financial incentives, risk assessment and soil clean-up standards. Fig. 1 shows an overview of main national policies and regulations for the management of contaminated soils introduced by several EU Member States, Norway and Switzerland during the last 25 years and that resulted from particular national interests. A detailed analysis of each situation is not included here although a number of relevant examples will be discussed next.

Early in the 1980s Norway defined very specific provisions related to soil pollution, by introducing the "Pollution Control Act" (based on the "polluter-pays" principle) and by assigning responsibilities for the regulation of contaminated sites (Ferguson, 1999). Ever since, several Guidelines for soil investigations, management of contaminated sites and risk assessment procedures have been introduced in this country. In Denmark, potential problems with contaminated sites (particularly deriving from landfills of chemical waste) were identified in the early 70s leading to the revision of waste regulations to deal with soil contamination arising from waste management and twenty years later, to the development of a broader "Soil Contamination Act", more able to deal with liability issues (Ferguson, 1999). Lekkerkerk, a town in the Netherlands, gained national notoriety in 1980 with the discovery of a large-scale soil contamination problem while a housing project was under construction. This problem contributed to the set-off soil remediation policy established by the Netherlands 25 years ago. The Netherlands was one of the pioneering EU Member States to establish

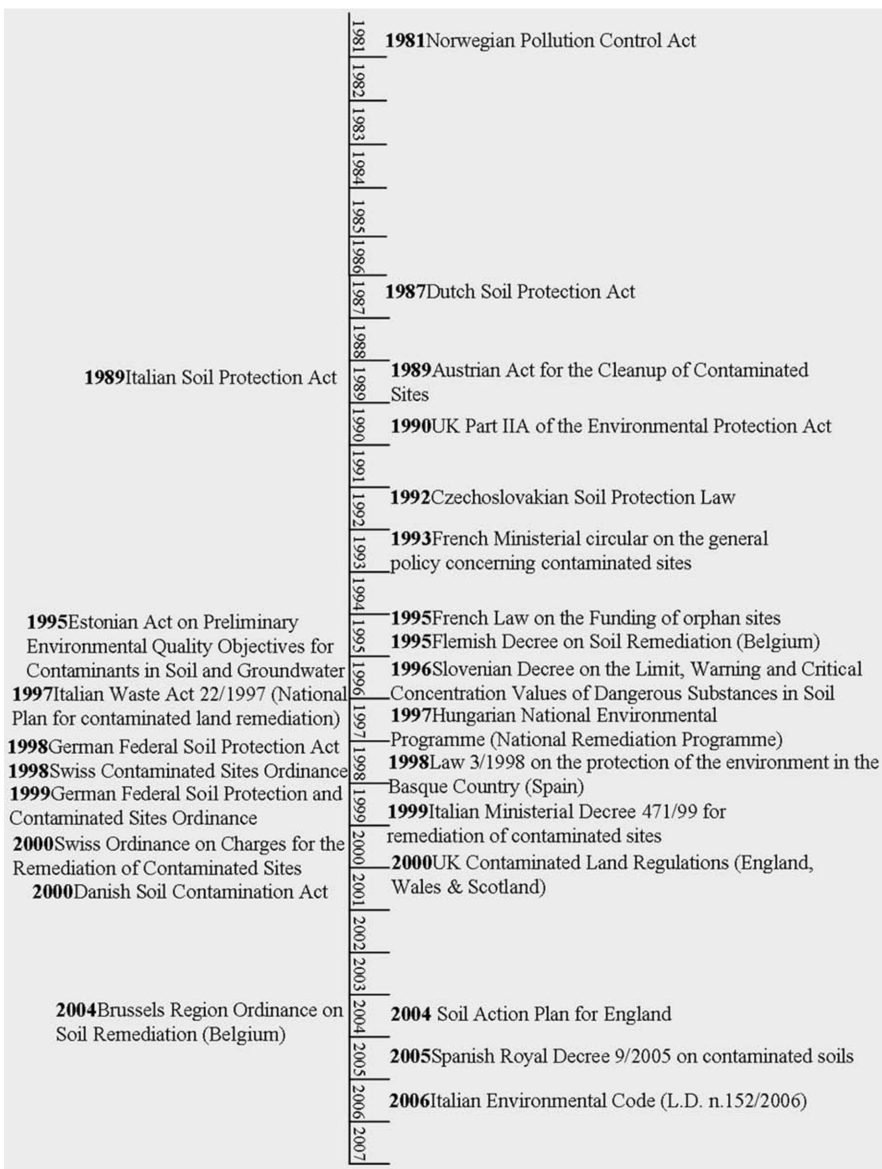

Fig. 1. Overview of national policies and regulations for management of contaminated soils in Europe.

specific legislation on soil protection. Soil remediation was given legal status in 1983, and later, in 1987 the Dutch "Soil Protection Act" came into force (Ferguson, 1999; Wesselink et al., 2006). The first steps of the Dutch soil policy included the definition of legal norms (intervention values) to regulate soil clean-up as part of a multifunctional remediation approach. The high costs associated to this multifunctional approach lead to the transition to a function-oriented remediation strategy in the 90s (Wesselink et al., 2006). Soil policy developments in the last 20 years in the Netherlands also included: the revision of remediation criteria; developments on soil quality objectives and risk assessment procedures; increase in flexibility for local authorities in regulating contaminated land; encouragement of local participation in the decision making process; a distinction between mobile and immobile cases of soil contamination; and the stimulation of private funding for soil remediation (Ferguson, 1999; Wesselink et al., 2006). A new framework of soil quality standards has been developed in the scope the Dutch Soil Quality Decree than entered into force in January 2008. This framework includes broad National standards derived for ten different soil functions (and simplified in three broad functions: nature/ agriculture; residential areas; and industry) on the basis of human health risks, ecological risks and agricultural production. It also includes a system to develop local standards (Pruijn and Walthaus, 2008; Wintersen and Posthuma, 2008). In brief the new system of standards comprises: target values (based on Dutch background values), intervention values (based on serious risk levels, determines the remediation urgency), and National soil use values (to determine remediation targets based on specific soil use related risks levels) (Walthaus and Wezenbeek, 2008). The National Soil Use Values are general soil quality standards to determine sustainable fit for a specific type of soil use, although local authorities may choose to develop their own Local Soil Use Values. National Soil Use Values were derived on the basis of ecotoxicological data, risk levels for human exposure (MPR, maximum permissible risks levels for humans) and the human exposure model CSOIL (Walthaus and Wezenbeek, 2008). If soil concentration values at a defined site surpass the intervention values, a stepwise risk assessment system (Soil Remediation Criterion) is applied to define the urgency of remediation (Walthaus and Wezenbeek, 2008). The newly developed Dutch soil regulatory framework also includes a risk toolbox, an instrument to support site-specific management of soil quality and soil use (Wintersen and Posthuma, 2008).

In the UK the first institutional mechanism to address contaminated land issues was the Inter-departmental Committee on the Redevelopment of Contaminated Land (ICRCL) which was set up in 1976 with the role of developing and co-ordinating advice and guidance on human health hazards arising from the re-use of contaminated land and co-ordinating advice on remedial measures. The ICRCL published the Guidance Note 59/83 (the 2nd edition, dated July 1987) to guide practitioners dealing with the many hazards and different types of historical contamination that defined Trigger values (threshold and action values) for three main groups of contaminants and for different planned land uses. These Trigger values were formally withdrawn in 2002 by DEFRA (Department for Environment, Food and Rural Affairs). Currently, in the UK, contaminated land is identified on the basis of risk assessment. In England, Scotland and Wales the contaminated land regime is implemented through The Contaminated Land Regulations (2000, 2001 in Wales) which enforces Part IIa of the Environment Protection Act (1990). Section 57 of Part IIa was introduced into the Environment Protection Act 1990 by the Environment Act 1995 and was implemented in April 2000 in England, in July 2000 in Scotland and in July 2001 in Wales. Part IIa introduced a new statutory regime for the identification, assessment and remediation of contaminated land in the UK and in response to this the DEFRA and the UK Environment Agency have developed risk-based procedures for assessing harm from contaminated sites to ecosystems (including surface waters) and human receptors. Comprehensive packages of technical guidance relevant to the assessment of human health risks arising from long-term exposure to contaminants in soil has been published by DEFRA and the UK Environment Agency (DEFRA and EA 2002a,b; DEFRA, 2006). In the contaminated land management revised approach, the UK has chosen to develop guideline values rather than standards, for the assessment of risks within the overall policy context of ensuring that land is 'suitable' for its actual or intended use. A multi-tiered approach was developed for the assessment of risks to both humans and ecosystems. The first requirement (Tier 1) for a human health risk assessment is the identification of linkages between contaminant, receptor and pathway in a properly justified conceptual model. The Source–Pathway–Receptor pollutant linkage concept is fundamental in defining the UK contaminated land regime and is described by Nathanail et al. (2005). The Tier 2 is a Generic Quantitative Risk Assessment evaluation and Tier 3 is a Detailed Quantitative Risk Assessment (Smith, 2006b; Carlon, 2007). Soil Guideline Values (SGVs) were calculated to be used in Tier 2 assessment through the Contaminated Land Exposure Assessment (CLEA) model. These SGVs are in fact intervention values that when exceeded may trigger further assessment or remedial action. The CLEA model is partially probabilistic and overall exposure needs to be calculated using the probability distribution functions of exposure parameters for each receptor (Carlon, 2007). It should be emphasised that this approach is advocated to allow prioritisation of sites for further investigation and subsequent "determination" of the significance of potential exposure on a contaminated site (requiring remediation within a defined period). The involvement of the local community in the decision making process from the earliest stages of the implementation of risk management is strongly encouraged by the UK contaminated land management system. Moreover, within the UK, soil remediation is closely linked to the planning regime and land development process. The "Part IIa" regulations essentially relating to land which would not be subject to development control.

In Belgium different soil policy formulations exist in Flanders and Walloon Region. Flanders adopted its Soil Remediation Decree in 1995 that contains an obligation to carry out an investigation at every transfer of land on which a "risk activity" is or has been developed. More recently (at the end of 2006) the Flemish Parliament adopted a new decree that will enter into force during 2008, although the basic principles of soil remediation criteria remain the same from 1995 (Dries et al., 2008). A distinction between "historical contamination" and "new contamination" is made and remediation which is primarily triggered by land transfer processes follows rules appropriate to each case. Soil clean-up standards follow a risk-based approach and are used to indicate a level of contamination that if exceeded could cause significant harm for human health. Five classes of land use have been defined and the Vlier-Humaan model is used to characterise pre-defined exposure scenarios and perform exposure calculations (Carlon, 2007). The legal framework for contaminated land management in the Walloon region is constituted by the Law of the Walloon government for the cleaning of contaminated sites and rehabilitation of brownfields (from 2004) and three kinds of risk-based standards have been developed for soil and groundwater quality assessment on contaminated sites: reference values, trigger values and intervention values.

Following a series of provisions related to remediation of contaminated land that were included in waste management policies, a Ministerial Decree concerning soil contamination (M.D. no. 471/99) came into force in Italy in 1999. More recently, in 2006, provisions for the management of contaminated sites have been included in the Legislative Decree no. 152/06 (revised by the Legislative Decree no. 04/08) which include the development of human-health site specific risk assessment whenever defined screening levels for soil, subsoil and groundwater are exceeded (D'Aprile et al., 2008).

The German Federal Soil Protection Act came into force in 1998, and the accompanying sublegal regulations in 1999 and integrates aspects of soil protection, remediation and pollution prevention (Carlon, 2007). The Act includes three types of risk-based standards:

Table 2
Overview of general practices for the identification and characterisation of contaminated sites in twenty three European countries (based on data from: Ferguson, 1999; CLARINET, 2002; CLARINET, Contaminated Land Approaches in 16 European Countries, Online on the internet http://www.clarinet.at/policy/, accessed: December 27, 2007)

Country	Most common approach for the classification of contaminated sites and definition of clean-up criteria	Specific contaminated land policy
Austria	Site-specific risk assessment	Yes
Belgium (Flanders)	Site-specific risk assessment (exposure assessment)	Yes
Bulgaria	Norms of maximum admissible contents of hazardous substances in the soil	No
Czech Republic	"ABC" limit values: A — background values; B — Possible possible adverse effects; C — Significant significant risk to human health and the environment. Risk assessment approach for state B criterion.	No
Denmark	Risk-based guideline values	Yes
Estonia	Target values and guidance values (based on risk for human health)	Preliminary
Finland	Risk-based guideline values	No
France	Site-specific risk assessment (tiered approach: preliminary site investigation; simplified risk assessment; detailed risk assessment)	No
Germany	Risk-based soil screening values (trigger values) and action values	Yes
Hungary	Limit values for soil and groundwater: A: background values; B: Threshold threshold values of contamination; C: Threshold threshold values of measures; D: target values. (based on Dutch, German, US EPA and Canadian guidelines)	Preliminary
Italy	Original 'limit value' approach has been included into a 'risk-based' multi-tier approach: Tier 1 — screening values or contamination threshold values; Tier 2 — site-specific target levels or risk threshold values	Yes
Latvia	Threshold values (Dutch threshold values used as reference)	No
Lithuania	Standards for contaminated soil and groundwater drafted (in line with Dutch threshold values). Site-specific simplified risk assessment.	No
Norway	Tiered approach: Tier 1 — generic target values ("TVs" based on existing Dutch and Danish guidelines); Tier 2 — site specific risk assessment (when TVs are exceeded); Tier 3 — Detailed detailed investigation	Part of "Pollution Control Act" and several specific Guidelines
Poland	Standards for environmental protection are generally based on fixed regulatory limits, but still no generic values for contaminated land. US EPA methods often used in site-specific risk assessments.	No
Portugal	Guideline values — Ontario (Canada) guideline values used as reference	No (under development)
Slovakia	Target values or permissible levels (former Dutch threshold values list was adapted in 1994)	Yes
Slovenia	Limit, warning and critical concentration values of dangerous substances in soil	Yes
Spain	Screening/guideline values and site-specific risk assessment	Yes
Sweden	Site-specific risk assessment (exposure assessment). The Swedish EPA defined guideline values for levels in polluted soils, for the most sensitive types of land-uses	No
Switzerland	Site-specific risk analysis. Intervention values for leachate and gaseous phase.	Yes
Netherlands	Risk-based norms (criteria): *target values* and *intervention values*	Yes
United Kingdom	Site-specific risk assessment based on Source–Pathway–Receptor approach and on the definition of "pollutant linkages". ". Soil Guideline Values have been derived using the Contaminated Land Exposure Assessment (CLEA) model for three land uses.	Yes

trigger values (that consider soil-to-human, soil-to-plant, and soil-to-groundwater pathways), action values (that consider soil-to-human and soil-to-plant pathways) and precaution values (to prevent new soil pollution). Whenever possible, considerations on the contaminants bioavailability are to be included in exposure assessments (Ferguson, 1999).

A Spanish regulation on contaminated soils was published in January 2005 (Royal Decree, RD 9/2005) and has been recently explained by Tarazona et al. (2005). This regulation is supported by the previous Spanish Waste Law (Ministerio de Presidencia 1998), and encompasses exclusively soils polluted by industrial activities. The RD 9/2005 defines a regulatory framework to establish those industrial activities that may result in soil contamination, defines a flexible and tiered system that includes risk-based Generic Values of Reference (GVRs) for sixty priority pollutants (and a methodology to derive these GVRs) and considers the possibility of further site-specific risk assessment. This regulation is risk-based and considers the protection of human and ecological receptors combining chemical and biological tools. The human health risk assessment is based on the analysis of relevant exposure routes for three land uses (industrial, residential and natural soil). The environmental risk assessment includes chemical analysis and direct toxicity testing, and covers three main ecological receptors: soil organisms, associated aquatic systems and terrestrial vertebrates. The inclusion of direct toxicity testing as a legal method for classifying a soil as contaminated is considered a key element of the Spanish approach.

Table 2 provides an overview of general practices for the identification and characterisation of contaminated sites in twenty three European countries. The overriding aspect of all these measures is that risk-based soil quality objectives (particularly risks posed to human health and the environment) are guiding the process. In some cases, risk-based national guideline values or norms have been developed for an effective and comparable classification of contaminated soils. These thresholds also indicate contamination levels above which soil remediation is needed/mandatory. In other countries, quality objectives and remediation targets are defined through site-specific risk analysis, and specific guidelines for the development of risk assessments are available. Furthermore, some European countries apply multi-tiered approaches that combine both the use of screening guideline values for the preliminary identification of contaminated sites, and site-specific risk assessments for more detailed investigations.

Issues related to the assessment of significant risk to human health and ecosystems from contaminated land originated most relevant discussions, particularly during the last decade, and the level of uncertainties associated to the risk assessment process is still considerably high. Nathanail (2006) presents a discussion on the appropriateness of generic and site specific criteria and on the advantages and drawbacks of each strategy concluding that there is a need for higher consistency on terms definition, their application and interpretation. Other authors (El-Ghonemy, 2005; Evans et al., 2006; Rothstein et al., 2006) present reviews of the gaps and risks of risk-based regulations which are most relevant for the on-going discussion — the authors describe how issues such as imprecision, uncertainties, operation and normative challenges carry significant implications for achieving regulatory targets.

In addition to the discussion on the generic vs. site-specific risk assessment approaches it is equally important to refer that the identification of receptors during the risk assessment process and whether these are humans and/or ecological systems has different implications for the development of the process and provide a most relevant discussion as well. Faber (2006) and Smith et al. (2006a) describe the state-of-the-art of site-specific ecological risk assessments in terrestrial ecosystems in Europe and the different frameworks used in different countries. According to Smith et al. (2006a), most countries use tiered approaches and generic guidelines for a first screening of ecological risk and are still at the stage of developing suitable frameworks. The needs for research on the derivation of robust and suitable ecological parameters, assessment criteria and guidance on measuring harm in relation to ecological functions are strongly emphasised (Faber, 2006; Smith et al., 2006a). Immediate questions arise when we consider whether soil functions can be quantified, and how robust procedures to measure harm in relation to function can be effectively developed. The experience from this diverse range of "common" approaches highlights the need for tests of significance in relation to appropriate receptors. The prioritisation of S–P–R linkages using common screening approaches is often undermined by natural variability of the environment coupled with differences in outcome for given land uses.

3.3.2. Other countries

Worldwide, as for example in the USA and Canada, specific regulatory measures have been implemented for management and remediation of contaminated sites over the last few decades. The awareness of human health problems associated to soil contamination in the USA (as for example at the "Love Canal" area) lead to the development of the Comprehensive Environmental Response and Liabilities Act (CERCLA) in 1980, also known as "Superfund" as this act introduced specific provisions for setting a fund for the remediation of contaminated sites. The Risk Assessment Guidance for Superfund, RAGS was published in 1989 and has been a major impetus to the application of risk assessment to the management of contaminated land at the USA. The practice of human and ecological risk assessment became the primary decision making tool to the management of contaminated sites, following the publication of the Risk Based Corrective Action (RBCA) standard by the American Society of Testing Materials (ASTM) in 1995 (Salhotra, 2008). Other landmark publications such as the US EPA's RAGS (Part D) Preliminary Remediation Goals (1994), the Brownfields Action Agenda (1996), The US EPA's Draft Vapour Intrusion Guidance Document (2002), state-specific RBCA programmes and voluntary clean-up programmes, define the general framework for contaminated sites management at the USA (de Sousa, 2001; Salhotra, 2008). All levels of government provide some type of funding and/or incentives for site remediation and re-development (de Sousa, 2001). Nowadays, the RBCA (or risk based decision making, RBDM, or risk informed decision making, RIDM) generic approach has been customized according to regulations and public policy of different States and are applied to sites with different sizes and complexities. The application of these processes includes four main elements: risk based site characterisation (that involves the collection of site specific data, the identification of exposure pathways and the quantification of risk for each pathways); risk assessment (integrated and multidisciplinary analysis of risks); and risk management and communication (involves measures to risk reduction and post risk management) (Salhotra, 2008).

In Canada, environmental regulatory issues including contaminated sites are shared among the different levels of government. Relevant legislation and administrative policies at the federal level include the "Canadian Environmental Protection Act" from 1998, the "Guidance Manual for Developing Site-specific Soil Quality Remediation Objectives for Contaminated Sites in Canada", 1996 and the "Recommended Canadian Soil Quality Guidelines" from 1997 (de Sousa, 2001). The two types of criteria, risk-based guideline values and site-specific risk assessment, are used for the investigation of contaminated sites and the definition of clean-up goals in Canada (de Sousa, 2001). National guidelines comprise both generic soil quality criteria and guidance for developing site-specific criteria. Each Canadian province and territory is responsible for the development of their own remediation criteria, guidelines for use at contaminated sites and procedures for the implementation of site-specific risk assessments (de Sousa, 2001).

Further than Europe and North-America, other countries as for example China (Luo et al., in press), South Korea (the Korean Soil Protection Act was established in 1995 and amended in 2002 and 2005 (Jeong et al., 2008)) and Japan (in Japan the Soil Contamination Countermeasures Law was enforced in 2003, as described by Ogata and Murakawa (2008)) are also currently involved in the development and implementation of regulatory decisions for risk-based management of contaminated land.

4. Discussion

4.1. Comparability of national contaminated land management regimes

Some similarities but also some differences can be found in national contaminated land regimes and associated risk management approaches across Europe and worldwide. Particularly in Europe, this poses important challenges regarding the implementation of an EU regulatory framework and the development of a concerted approach to deal with common problems.

In general, most relevant elements that are common to the various national programmes dealing with soil contamination (although sometimes differently dealt with) are:

- Liability and funding issues: in general the "polluter-pays" principle is applied as far as possible but assigning liability on soil contamination cases is not always an easy task; several countries have defined specific approaches to assign legal responsibilities, to deal with orphan sites, and to combine private with public funding for soil remediation (e.g. base public funding on specific taxes). In the UK, for example, the private sector drives and funds the majority of land development and remediation projects (CLARINET, 2002). In some countries (e.g. Netherlands) there is a hierarchy in terms of liability — polluter, land owner, government and there are specific mechanisms for the protection of innocent land owners (de Sousa, 2001).
- Level of intervention: to achieve soil quality objectives in each country, action is required at different levels and falls under different jurisdictions: national, regional and local. European countries have different administrative structures and in some cases, regulatory measures to manage contaminated sites vary even within the country (e.g. Belgium) or are adapted concerning regional or local specificities (e.g. Spain). In some countries as for example the UK, local authorities have responsibility for dealing with effects on public health from land contamination, and development on or near contaminated sites (Ferguson, 1999).
- Historical contamination: many sites in Europe have been severely contaminated by a wide range of activities in the past. There is a legacy of historical soil contamination (with levels and types that vary from country to country) deriving mostly from chemical industry and waste landfills (metals and organic compounds), oil industry and petrol stations (mostly organic compounds), mining activities (metals), agriculture (pesticides, fertilisers and metals), service stations and dry cleaners (solvents) and/or abandoned military sites (shooting ranges, airbases, fuel stocks, harbours, storing facilities, etc) contaminated with metals, organic compounds and explosives. The existing EU policies that tackle soil protection issues do not apply to contamination which occurred prior to its entry into force. Historical contamination is expected to be addressed by the proposed EU SFD. Nevertheless, several countries (e.g. Netherlands, France, Spain, and Hungary) have already introduced integrated nation-wide programmes that often include national inventories of contaminated sites and remediation strategies, setting remediation targets and the definition of implementation, financing and progress reporting structures.
- Multifunctional vs. function-oriented approach: the general tendency even in cases where national policies first tackled a multifunctional remediation approach (e.g. Netherlands) it is to move towards "fitness-for-use" remediation objectives in all countries. In some cases where generic criteria have been developed, these relate

to specific land uses. Site-specific risk assessments are generally conducted considering present/ future land use of the site under investigation.

- Use of limit-values and/or site-specific risk assessments: a variety of approaches have been applied across European countries during the past few years to develop the quality objectives for contaminated sites and to define soil clean-up criteria.

In countries where a framework for contaminated land management is in place, the national land use and spatial planning systems play an important role in the remediation and clean-up of contamination. Their action is generally a response to the needs associated to land transfer, site development and re-development processes. Although the planning and contaminated land regimes are generally two distinct systems, there is a degree of interaction between them. Moreover, as it is common that both national and local authorities play a role in the process, the intervention of national authorities is mostly commonly required when:

– dealing with funding issues;
– remediating historically contaminated sites where no liable party can be identified (the so-called “orphan sites”);
– defining strategies for soil pollution prevention and control; and,
– defining national soil quality monitoring and protection strategies.

National interventions are particularly devoted to the definition and management of areas of potential risk at national level and the prevention of future risks, while regional/local interventions are much more focused on the assessment of actual risks at regional/local level and their minimisation. Table 3 shows a contaminated land management matrix that includes an overview of the main features which are commonly characteristics of interventions by national and regional/local authorities in contaminated land management. There are many opportunities for sharing information and for the integration of both levels of intervention. Therefore, an important challenge in the production of robust decisions for contaminated land management is data integration, particularly when dealing with different spatial scales of intervention. Integrated layered responses have to be developed to deal with different levels of action, analysing the situation at different scales and incorporating uncertainties from different sources.

Vegter (2008) has described three generations in soil policy making which, according to the author, may be found in Europe: Generation 1 (Command and Control regulations by national authorities — early policies that arose in the 1980s that included systematic inventories of contaminated sites and the classification and prioritisation of sites according to numerical standards); Generation 2 (Flexibility in national regulations, room for local specific decisions —flexible, risk based land management and fitness-for-use decision making that considers spatial planning priorities and includes public–private partnership financing); and Generation 3 (Regulations are used to create opportunities and to remove barriers for remediation by private parties — has just started in some countries, focus on the economic and social viability of the redevelopment of a site and aims at managing liabilities and increasing voluntary remediation by private parties). Therefore it is most needed and challenging to implement a flexible EU framework legislation that sets common grounds for contaminated land management throughout Europe and ensures the improvement of soil conditions in both countries where the extent of site contamination problems is still unknown and in countries which have dealt with contaminated land for thirty years and where political attention has shifted from Generation 1 for Generation 2 or 3. Harmonisation of approaches for the definition of significance of identified risks and their prioritisation, require further discussion at an EU level as they are fundamental to allow regulators from each Member State to proceed and to enable site remediation to take place. A most relevant work on this field is currently being developed by the European HERACLES expert network (Swartjes and Carlon, 2008).

4.2. The challenges in the development of national soil policies and in the development of national remediation programs

We present a framework to support the development of national contaminated land management programmes in the context of the implementation of the EU SFD. We suggest driver–pressure–state–impact–response (D–P–S–I–R) framework (reviewed and modified from EEA, 2000) as a methodological approach for providing an information framework to support interventions on contaminated land management at a national level, focusing policy and strategic planning issues and a Source–Pathway–Receptor framework (Petts et al., 1997) as guidance to action at the site level. A D–P–S–I–R structure defining processes in time affecting soil and allowing a better understanding of dynamic processes underlying soil functions and strategies with the potential to reduce threats has already been used as an operational framework for the EU Thematic Strategy for soil protection by the Technical Working Groups (TWGs) involved in its development (Blum et al., 2004; Bouma and Droogers, 2007). A combination of both frameworks and levels of intervention together with the type of information required to support contaminated land management is shown in Fig. 2. Key aspects of this framework are the characterisation of processes leading to changes in soil quality and associated impacts that may occur in three particular domains: risk to

Table 3
Contaminated land management matrix for two levels of intervention

	National level of intervention	Regional/local level of intervention
Nature	Normative: definition of a national soil policy framework and regulatory strategy Relates to the national land use planning system and to other national policies and strategies such as environmental and public health protection, agriculture, industry, mining, oil and gas Relates to EU policies and international conventions and agreements and reports to international bodies such as EEA Qualitative, conceptual and dynamic	Site specific Relates to local land development plans Reports to local authorities, land owners, insurance companies Quantitative, deterministic/probabilistic
General framework	D–P–S–I–R	Source–Pathway–Receptor
Scope	Strong focus on soil pollution prevention and control General guidance: definition of national environmental protection objectives and remediation targets Deals with funding, liability and enforcement strategies Historical soil contamination National monitoring Focus on soil polluting sectors and activities Main focus on risk prevention and management	Strong focus on clean up of polluted sites Action oriented: site clean up criteria and site-specific action values Deals with transfer of land, site development and re-development issues Present contamination Site assessment Focus on soil polluting projects Main focus on risk assessment and reduction
Data and information sources	National databases, metadata, historical records and desk studies Background concentrations of trace elements at national level	City departments information, field data and detailed site investigations Regional/local background values

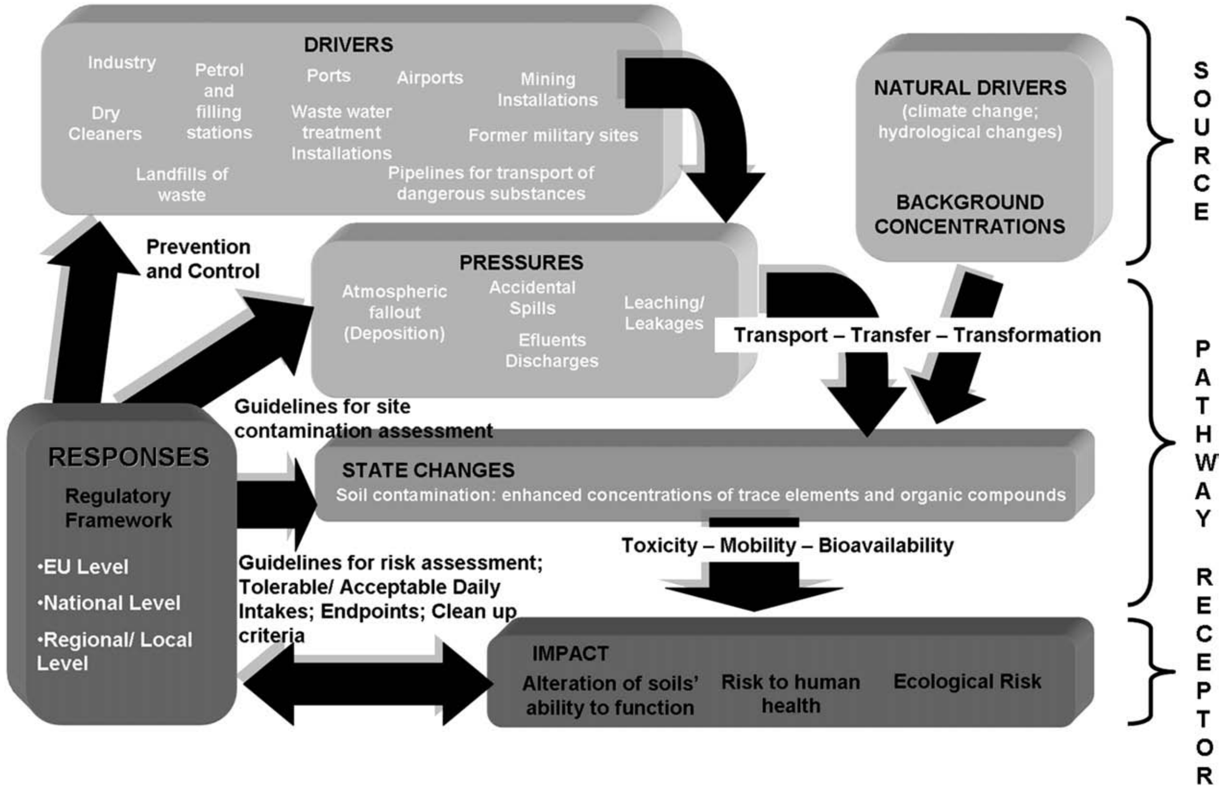

Fig. 2. General contaminated land management framework.

human health, ecological risk, and alteration of soils' ability to function. While an extensive body of scientific literature exists for the first two domains (see above), the characterisation of different soil functions and the identification of respective indicators is still an area with critical research needs. The D–P–S–I–R framework allows an overview of contaminated land problems and potential risks at national level, while the Source–Pathway–Receptor framework (chain or linkages) focus on the development of detailed site-specific investigations to link site contamination with direct and indirect exposure pathways to potential targets or receptors and allow a test of "significance" to be applied. Whenever there is site contamination there will be risk if there is a pathway by which the contaminant may reach a sensitive receptor (Petts et al., 1997). This approach is currently followed for site investigations and selection of remedial options in the UK, as defined by the UK Contaminated Land Regime (DEFRA, 2006).

The most relevant data requirements for the development of a country specific D–P–S–I–R framework are:

- Drivers: Identification of most relevant sources of soil contamination at national level and possible transboundary contamination sources;
- Pressures: Identification of most relevant contaminants (both threshold and non-threshold contaminants) associated to country specific key soil contamination problems;
- State: Development of information on natural background concentrations of relevant contaminants, on national soil types and variability of relevant soil properties, and on the preliminary identification of potentially contaminated sites;
- Impact: Development of country specific risk assessment approach — this should include the definition of a risk assessment conceptual model.

The definition of a conceptual risk assessment model is a crucial step in the implementation of a national soil policy. This model needs to:

- Identify relevant receptors (conceptual models already in place have defined objectives for the protection of specific receptors such as: human health, terrestrial and aquatic ecosystems, groundwater, surface water, and agricultural production);
- Identify relevant exposure pathways (and associated exposure variables and parameters) — conceptual models already in place are based on the consideration of several exposure pathways such as soil outdoor and indoor pathways, soil derived diet exposure, soil–groundwater pathways, soil–surface water pathways, soil–plant pathways; and
- Select toxicological data to be used.

The Response (from the D–P–S–I–R framework) that is expected from the regulatory agencies is in this case the development of a Contaminated Land Legal Framework (CLLF). This CLLF must consider:

- The selection of sensitive land uses (several soil functions have been selected in EU countries such as: nature, agriculture, public green areas, residential with or without garden, and industrial;
- The derivation of soil screening values (or the definition of a methodology to derive them) and soil clean-up criteria;
- The development of site-specific investigation guidelines;
- The definition of a risk management strategy and national remediation targets;
- The integration of the CLLF with other national environmental policies.

The development and the implementation of a CLLF require concerted action from several stakeholders: policy and decision makers; private sector operators; Research and Development (R&D) community; and citizens in general.

Furthermore, the definition of a CLLF implies several decisions from decision makers. Some of these decisions are political choices, some are regulatory or management decisions and some are technical or science-based decisions. Examples of political choices include, as described by Salhotra (2008): the selection of protected receptors; the definition of acceptable levels of health risk and the consideration of acute and/or chronic risks; the choice of fate and transport models;

the selection of chemicals of concern; the implementation of institutional controls as a risk management strategy; the consideration of the additive risk related to the presence of multiple chemicals of concern and multiple exposure pathways; emphasis on resource protection vs. risk reduction.

Based on an assessment of the history of contaminated land regimes already implemented in several countries, the key legal and management decisions for countries to establish soil specific legislation are as described next:

a) Organisation of government and non-government administrative structures (from national to local level) to deal with soil policy development and implementation aspects, including efficiency and impact assessment mechanisms;
b) Integration of soil policy with other national environmental and planning policies and environmental protection practices and mechanisms;
c) Definition of a hierarchical structure for issues of liability and specific funding schemes (e.g. development of public funding programmes for high risks sites or "orphan" sites that may be supported by specific environmental taxes);
d) Development of incentive mechanisms for increasing private funding of site remediation projects and voluntary plans, to extend the market driven process, active in many countries;
e) Development of well equipped national operational research programmes — these programmes should consider research on the assessment of impacts of site contamination on soil function, on the integration of soil function analysis into site development and on the definition, on the quantification and assessment of significance of risks posed by contaminated sites, and on the development of cost-effective remediation solutions;
f) Raising public awareness and convincing several stakeholders of the importance soil protection issues;
g) Development of highly effective communication and stakeholder engagement systems.

Science-based decisions are those associated to scientific aspects of the risk characterisation and assessment processes and are those expected to offer more possibilities for the harmonisation of methodologies among different countries. Political and regulatory or management choices are by nature, country specific.

5. Conclusions

At the heart of the process for managing contaminated land there are issues of human and animal health protection; ecosystems and biodiversity conservation; water and air quality; and crop and food safety that are common among all European countries. Although certain EU Member States have already contaminated land regimes in place, many others still don't. Moreover, considering that certain contaminated areas have transboundary nature and that there are soil contamination problems which are common to several EU countries (in some cases associated to huge costs for society) there is a need for a concerted action within the EU. There are technical aspects of site characterisation, risk assessment and remediation that can be harmonised at the same time that there are trans-scientific aspects of these processes that require political choices and that need to be customized by EU Member States. In addition, it is important to be aware that pollution does not recognize geographic boundaries and that the problem of soil contamination is also being addressed by other countries outside EU. Therefore the results and the sustainability of the implementation of current practices should be further analysed from a global perspective.

The analysis of almost three decades of national and international experiences in dealing with soil contamination issues has highlighted some policy issues. An effective contaminated land regime can be derived from lessons from past actions and practices in several countries. A contaminated land management strategy must consider the key stages: dealing with historically contaminated sites, managing present contamination and preventing future contamination of land. Where land is statutorily defined as contaminated land, and particularly where it is proposed to build on a contaminated site, an effective remediation option has to be selected on the basis of a national remediation strategy and on the basis of national provisions on risk assessment. For the process to be robust and effective, a proper interaction between the national level of intervention and local authorities — or in other words, the interaction between the planning and the contaminated land regimes has to be effective. The use of a framework that combines the D–P–S–I–R structure of policy evaluation with the Source–Pathway–Receptor approach to health risk assessment is able of supporting the development of effective country specific regulatory decisions for contaminated land management at the various levels of intervention.

Acknowledgements

The corresponding author would like to acknowledge the financial support from the Portuguese Foundation for Science and Technology (FCT), under the PhD grant: SFRH/BD/30118/2006.

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