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ARTICLE *in* ENVIRONMENTAL SCIENCE & TECHNOLOGY · JANUARY 2011

Impact Factor: 5.33 · DOI: 10.1021/es101463y · Source: PubMed

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From Chemical Risk Assessment to Environmental Quality Management: The Challenge for Soil Protection†

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Received May 1, 2010. Revised manuscript received July 29, 2010. Accepted August 4, 2010.

The 40 years that have passed since the beginning of the 'environmental revolution' has seen a large increase in development of policies for the protection of environmental media and a recognition by the public of the importance of environmental quality. There has been a shift from policy in reaction to high profile events, then to control of releases to single environmental media, and to the present position of moving toward integrated management of all environmental media at present. This development has moved away from classical chemical risk assessment toward environmental holism, including recognition of the ecological value of these media. This work details how policy developments have taken place for air and water, with examples from the USA and EU, in order to compare this with policy development regarding soil. Soil, with quite different policy frameworks and distinct uses, understanding, and threats compared to other environmental media, is currently attracting attention regarding the need for its protection independent of use. Challenges for soil policy are identified and evaluated, and recommendations on how these challenges can be overcome are discussed with relevance to water and air protection policy.

Introduction

The preceding 40 years has seen a large increase in the number of policies, and regulatory agencies, for the protection of the environment. Public environmental consciousness has increased dramatically over this period, and Earth day 1970 is commonly cited as the beginning of the environmental revolution (*1*, *2*).

† This manuscript is part of the Environmental Policy: Past, Present, and Future Special Issue.

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Early environmental legislation developed largely in reaction to high profile events. There was a subsequent move toward legislation that aimed to address impacts to human health, and today it covers 'environmental health' as a whole. Policy has developed to stop deliberate pollution, to then prevent pollution on a wider scale, and finally to move toward a more holistic environmental quality management approach. Driven by protection of health, increases in public consciousness, and requirements for better management of resources, environmental quality particularly of water and air has been a main focus of environmental policies. The environmental policy field has had a long history of public interest and participation (*3*, *4*). Future environmental policy is likely to involve the public in the decision making processes even further, with interactions explicitly prescribed in policy documents. New and emerging policies have included aims to improve public understanding of environmental problems and involvement in the legislative process (*5*, *6*). The last 40 years has seen an increase in collection of environmental data, a need to better communicate findings to the public, and in some cases collection of such data by the public (*7*). With an increase in environmental protection and consciousness, both from public and policy spheres, there is potential to improve public engagement through participation in environmental analysis and better environmental quality management.

Soil protection and management have been featured in policy discussions since the late 1970s. The topic has recently been of interest in development of emerging policies, particularly with regards to the role of soil as a resource, independent of the functions that it carries out. Soil provides multiple important functions including provision of food, biomass, and raw materials, a platform for human activities and landscape, an archive of heritage, acting as a habitat and gene pool, and filtering and transforming substances including water, nutrients, and carbon (*8*, *9*). The move toward environmental holism that has been driving policies for air and water has proven to be a challenge for soil management that faces some quite different issues which have had and will have a considerable impact on policy formulation. While air policy focuses on chemical quality, and water policy focuses on both quantity and chemical quality, soil has other issues due to its multiple functions. Policy developments have also been effected by land ownership, particularly with respect to contaminated land, by most soil not being readily visible, and being subject to slow processes compared to water and air.

The objective of this work is to evaluate how environmental protection policies have evolved for air and water in order to compare this with how policy has developed for soil protection. The scope of the work will be to look at not just contaminated land policy but to relate this to the wider soil quality concept which addresses all soil degradation processes. Key challenges for the development of soil protection policy are identified, and recommendations for how these could be resolved are discussed.

Water Policy Development

There has been acceptance of a systemic approach for water management, which can be illustrated by a number of international conventions (*10*–*12*). Many states have adopted an approach to water resource policies that shifted from fragmented to integrated water resource management.

US policy before 1960 treated water pollution as a local problem, with slow development of regulations, focusing

10.1021/es101463y

Published on Web 08/24/2010

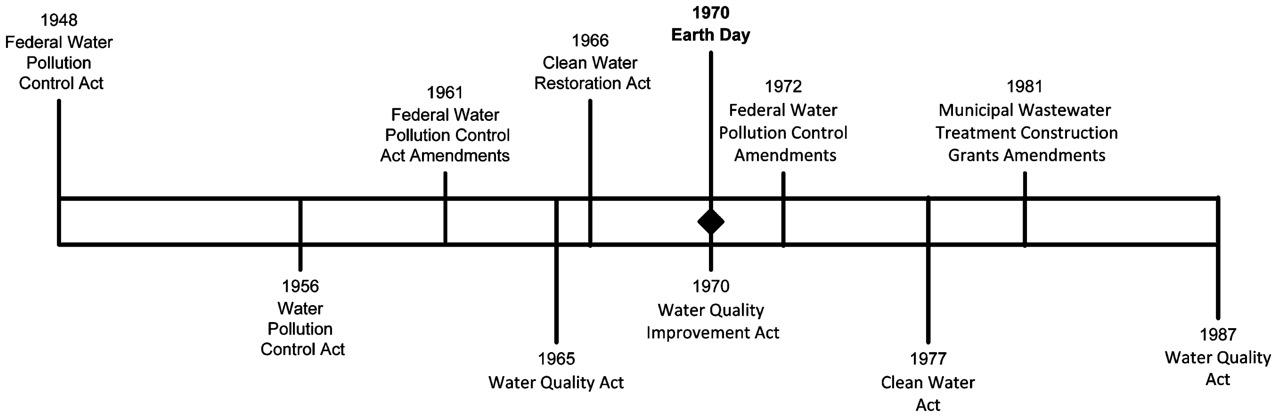

FIGURE 1. Major US Water Quality Policy and Amendments timeline.

principally on drinking water purity, and municipal sewage disposal rather than industrial discharges. The 1948 Federal Water Pollution Control Act was modest and mandated a series of studies and limited projects (*13*). Since the 1948 act, there have been some major developments, Figure 1. In the 1960s there was considerable investment in wastewater treatment, and 1965 saw the first explicit national policy for water pollution prevention and control.

In 1970, the establishment of the Environmental Protection Agency (EPA) allowed federal regulation of water (*14*), which was then strengthened with the passing of the 1970 water quality improvement act, which introduced a state certification procedure to prevent degradation of water below applicable standards (*15*).

The amendments of 1972 further improved earlier regulations, limiting pollutants at source, prohibiting discharges without permit, and prescribing feasibility based controls for point sources (*16, 17*).

The major amendments in the Clean Water Act (CWA) 1977 expanded and specified the EPA's mandate to control the release of toxic pollutants into sewers and surface waters (*18*). The act retained the feasibility based focus; however, it modified implementation of the 1972 standards by giving the EPA authority to introduce pollution control programs. It revised rules governing pretreatment, and a variety of exemptions, waivers, and modifications of feasibility based standards were authorized by the act (*16*). The amendments introduced a grants program for rural land-owners using 'best management practices' to control diffuse pollution (*19*). The 1981 Municipal Wastewater Treatment Construction Grant Amendments not only revised support to publicly owned treatment works but also affected the regulatory provisions of the CWA (*16, 20*). The CWA became the Water Quality Act 1987, replacing the construction grant program with a loan fund, and introducing control of nonpoint source pollutants, addressing cleanup of pollution hotspots, restoring ecologically important bays and estuaries, monitoring water quality in the great lakes, and establishing a stormwater program (*16, 17*).

Policy for the protection of water in the USA has shifted, since the 1972 amendments, from a program by program, source by source, and pollutant by pollutant approach to a more holistic watershed based strategy; emphasizing protection of healthy waters and restoring impaired ones on a watershed basis (*11*).

In the EU there has also been a similar change in water protection policy since the 1970s. Development of EU legislation for water resources can be defined in 'waves', the first of which including the Surface Water Directive (1975) and Drinking Water Directive (1980) which focused mainly on water quality standards and protection of surface waters allocated for drinking. The 'second wave' of legislation set acceptable water quality standards but also aimed to control emission levels to achieve the standards; it included the Urban Wastewater Management Directive (1991), the new Drinking Water Quality Directive (1991), the Nitrates Directive (1991), and the Directive for Integrated Pollution and Prevention Control (1996) (*21, 22*). The EU Water Framework Directive (WFD) (*6*) is the 'third wave' of EU water legislation. The WFD is a policy providing a common framework for water management and protection within the EU. It follows an integrated approach, built upon directives to protect water quality and those limiting emissions and aims to harmonize existing water policy and improve water quality in all aquatic environments (*21*). The directive recognizes that effective management of water resources will only be achieved by integrated management of all ecosystem components at the catchment scale (*23*). States are required to prevent deterioration of the quality of waters as well as achieve good chemical, ecological, and quantitative status in the aquatic environment by 2015, attaining at least good ecological and chemical status (*24, 25*). Ecological status is an expression of the quality of the structure and functioning of surface water ecosystems as indicated by biological, chemical, physiochemical, and hydromorphological quality elements (*26*).

The new approach to water policy in the USA and EU shifts from sectorally fragmented to integrated water resource management, from water related sectors operating independently to integrated consideration of supply, pollution control, agriculture, hydropower, flood control, and navigation (*11*).

Air Policy Development

Like water policy, air policy has developed significantly since the mid twentieth century. In the USA the first piece of federal air quality legislation was the 1955 Air Pollution Control Act which authorized funds for state research and training and which was strengthened further in 1959 and 1962 (*27*); Figure 2. In 1963 the Clean Air Act (CAA) was passed, providing permanent support for research, support for development of pollution control agencies, and cross-boundary air pollution assistance.

The CAA Extension of 1970 charged the EPA to establish national ambient air quality standards (NAAQS) and to create regulatory guidance to use in developing state implementation plans (SIP) to achieve NAAQS. The extension created a new source performance standards (NSPS) program that authored the EPA to set stringent control technology requirements for new, modified, and reconstructed sources. The 1970 extension was the first to regulate air pollutants and establish emission standards for motor vehicles and mobile air pollution sources (*28, 29*).

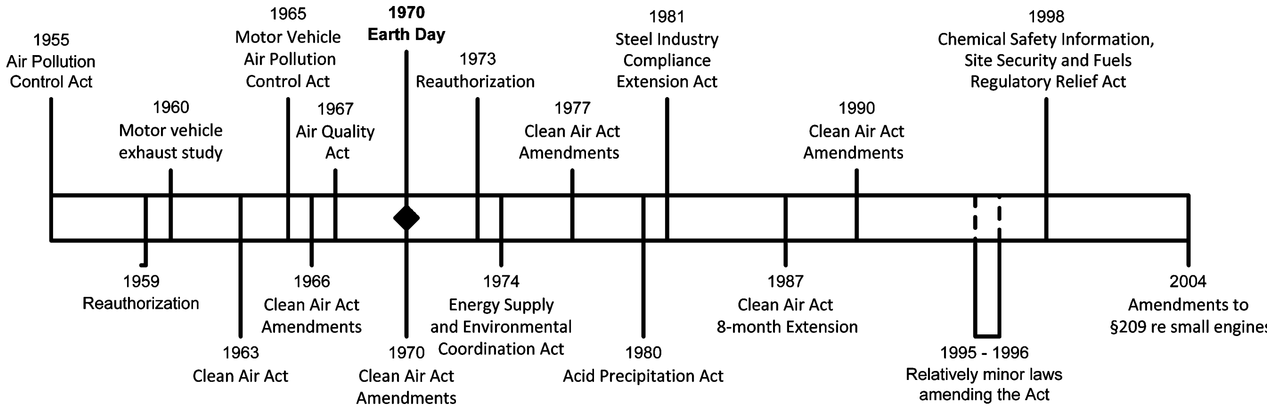

FIGURE 2. Major US Air Quality Policy and Amendments timeline.

The next major amendment to the CAA was in 1990, this is accepted as putting the goal of clean air back on track after a number of problems with air quality management (*30*). The amendments introduced provisions to classify nonattainment areas, tightened automobile and other mobile source emission standards, required reformulated and alternative fuels in the most polluted areas, revised the air toxics section, established a new program of technology-based standards, and addressed the problem of sudden, catastrophic releases of pollutants. The amendments established an acid rain control program, required a permit program for the operation of major sources of air pollutants, implemented the Montreal Protocol to phase out most ozone-depleting chemicals, and updated enforcement provisions (*31, 32*).

Despite problems with the current air quality management framework in the USA where a number of areas of concern can still be frequently highlighted, the overall progress in policy has been significant in addressing major issues in air quality management (*30, 33*).

In the EU air quality is one of the most active areas of policy making, and since the 1970s policy has developed extensively (*34*). The 2005 EU Thematic Strategy on Air Pollution (*35*) established interim objectives for air pollution in the EU and proposed appropriate measures for achieving them in order to minimize impacts on and risks to human health and the environment. The strategy included a draft framework directive that proposed that a number of existing instruments were revised and combined into a single act (*36*). This directive on ambient air quality and cleaner air for Europe entered into force in 2008, merging most of the existing legislation into a single directive with no change to existing air quality standards. The directive set new air quality standards for particulates including limit value and exposure related objectives with an exposure concentration obligation and exposure reduction target. It also introduced the possibility of discounting natural sources of pollution when assessing compliance against limit values and time extensions for complying with limit values (*37*). Such policy dictates member states regulations and the large developments since introduction of instruments such as the UK Clean Air Act 1956 demonstrate the move from reactionary actions to integrated air quality management.

The State of Soil Policy

The increasingly integrated nature of both water and air management policies in the US, EU, and internationally has not been addressed in the same way or extent for soil. Due to the multiple functions that soils provide there are a variety of drivers for soil protection legislation (e.g., soil contamination, construction, agriculture, amenity value). Although recent policy developments have centered on soil contamination, agriculture was the drive for initial soil policy formulation. Agriculture has been regulated across the world for hundreds of years (*38*). The first soil protection legislation in the USA was however in reaction to the threats of soil erosion and agricultural overproduction during the 'dust bowl' in the Midwest USA. The Soil Conservation Act (1935) is an important piece of national soil protection legislation which has had a large impact on both national and international policy (*39*). One of the main features of the act was to establish the Soil Conservation Service to provide technical support for the control of erosion. The act was followed by the Soil Conservation and Domestic Allotment Act (1936) with an objective to reduce production of surplus crops by giving payments for improved land use and conservation practices (*38*). The 1936 act marked the beginning of a number of policies aimed at commodity supply management and soil conservation (*40*).

The advent of environmental protection legislation addressing soil contamination came much later, in part in recognition of the impact of chemicals on the environment. Regulation before the 1980s was largely under more general legislation (*41*). Early policy was perceived in terms of relatively rare incidents, with poorly known but possible catastrophic consequences for human health and the environment (*42*). Such policies sought maximum risk control, with pollution being completely destroyed, removed, or contained. In the USA events such as the Love Canal incident is cited as a major driving factor behind the 1980 Comprehensive Environmental Response, Compensation and Liability Act (CERCLA) (*43*−*48*). CERCLA allows fast response to pollutant releases and public health and environmental protection by cleaning up the worst hazardous waste sites. The act imposes costs on those responsible and establishes a fund to finance responses where liable parties cannot be found or cannot pay (*49*).

As a reaction to events in The Netherlands the 1983 Soil Cleanup Interim Act was enacted (*50*). The corresponding Soil Remediation Guideline outlined how to take action on soil contamination and included three judgment based soil and groundwater quality standards (*51*). In 1987 the Soil Protection Act was introduced establishing a number of measures including accountability and financial responsibility for soil contamination. A review into the Soil Remediation Guideline led to development of the Soil Protection Guideline, which was incorporated into the Soil Protection Act in 1994. This laid out intervention values outlining action on soil contamination and included soil and groundwater quality standards based on risk principles to protect potential receptors and seen as 'best practice' and adopted by many countries (*51*). The risk based methods combined with the 'multifunctionality' approach meant that the most stringent standards were applied and cleanup standards were high (*41*).

As knowledge of the extent of contamination developed, so did perception of the problem. Contaminated soils were no longer seen in terms of severe one-off incidents but rather infrastructure problems of varying intensity and significance (*52*). It is recognized that drastic risk control is usually unnecessary when taking into account the potential adverse effects of contamination for current and intended land uses and the environment. Cleaning up all sites to background levels suitable for the most sensitive possible land uses is not technically, financially feasible, nor sustainable (*53*). An underlying philosophy in many countries is now of fitness for use, where contaminated soils should be restored according to planned usage. Land can be seen as 'fit for use' when it can be used for a particular purpose without posing unacceptable risk to human health or the environment (*54*). In 1997 The Netherlands shifted its soil remediation objectives, replacing its strict 'multifunctionality' approach with function-orientated and cost-effective remediation; this changes remediation objectives that applied across land use with those that take the land use into account (*55*).

Within the EU although soil protection is covered by some sector-related policy measures such as the Sewage Sludge Directive (1986), the Integrated Pollution and Prevention Control (1996), waste management laws, chemicals law, and air pollution law, there is currently no specific legislation relating to soil protection. While air and water resources are protected by EU law, soil degradation remains a serious problem in Europe (*9*). Despite this the recognition of the trans-boundary character of soil degradation processes has focused attention on the need for multilateral soil protection policy (*39*). In 2006 the EU adopted the Soil Thematic Strategy, providing a common framework for soil protection. The strategy is an attempt by regulators to integrate the different policy drivers to soil protection policy (e.g., agriculture and contaminated land) into one coherent legislative approach. It has identified a number of threats having consequences potentially detrimental to water quality and quantity, human health, climate change, biodiversity, and food safety (*8*). A knowledge based approach to soil monitoring, aimed at delivering soil protection and sustainable use, is introduced and required by the strategy (*56*−*58*).

The thematic strategy includes a draft Framework Directive for the protection of soil that requires integration of soil protection into all policy making, prevention of degradation and pollution of soils, implementation of risk/priority areas and action programmes for soil threats, limitation and containment of soil sealing, and identification and remediation of contaminated sites (*59*). The proposed directive has been subject to much discussion and opposition to the proposal has been expressed on the grounds of subsidiarity and proportionality, expected costs and administrative burden. Development has been slow for reasons including problems agreeing on an approach for identifying geographical "risk areas" or "priority areas" (*60*) and concern in relation to the methodology for identifying contaminated sites (*61*).

The lack of mechanisms for assessment of soil quality that integrate the different policy drivers can be attributed to issues associated with the wider soil quality concept which has featured in scientific and policy discussions since the 1970s (*62*). Alexander (*64*) first suggested the development of soil quality criteria (separate to contaminated land), and later in the 1970s it was suggested that soil quality should be evaluated in relation to land function (*63, 64*).

Interactions with holistic environmental quality, water and air quality were discussed in the mid 1980s (*65*), with some progress in the 1990s including suggestion of minimum data sets for soil quality assessment, discussion about the differences between soil health and soil quality, and a differentiation between the intrinsic properties of a soil and soils productivity as a result of management practices (*66*−*72*). Doran and Parkin (*75*) and Pierce and Larson (*74*) developed the definition further by including key soil functions, fitness for use and the dynamic state of soils in the definition of soil quality, and soil protection policy, which clearly inspired later soil quality definitions (*58, 64, 70, 73*−*75*).

Despite discussion surrounding the soil quality concept consensus among the scientific community on a precise definition has never been reached. There have been a number of reservations expressed in the scientific literature that have disputed the relevance and impact of soil quality (*76*). Objectors have focused on the subjective nature of soil quality assessment, the lack of mechanically based assessment methodologies, and importantly that soil quality assessment fails to integrate simultaneous, diverse, and often conflicting soil functions (*77*−*83*).

The Challenge for Soil Protection Policy

A shift from reactionary environmental policy making to chemical risk assessment and then toward environmental holism has occurred over the past 40 years. For water, air, and soil initial policies for its protection were very much in reaction to high profile events. For soil this led to an emphasis on contaminated land, and a substantial policy area has developed to deal with contaminated sites. The challenge for policy makers tasked with the protection of soil is to keep up with policy developments in water and air quality management where there has been a move toward holistic management and protection policies. For soil this is difficult as contaminated land which focuses on the presence, movement, and availability of pollutants must be integrated with other aspects of soil quality (e.g., biological, physical and other chemical aspects), requiring a holistic soil quality assessment that addresses both. The dichotomy between the different interested parties (e.g., agriculture and contaminated land), a product of the multiple functions of soil, is one of the persistent reasons for the lack of any comprehensive and integrated legislative approach to soil protection. Problems with the often multiple and conflicting functions of soil, as expressed with the concerns surrounding with the soil quality concept, introduce additional problems, particularly so when contaminated soil is integrated with other aspects of soil quality. A further challenge for soil protection policy is to take into account the complexity of environmental situations (e.g., different soil types) within the geographical area covered (*9*).

Despite the holistic policies seen for air and water similar emerging regulations for soil are still controversial, for example the proposed EU Framework Directive on soil protection which has attracted a high level of opposition. The proposed directive attempts to combine the chemical risk assessment framework, dealing with contaminated land, with other threats to soil. Despite the long development timeline of such legislative instruments consensus within the EU is low. The lack of consensus and no established and accepted protocol for wider soil quality assessment have hindered the assessment and management of soil. This lack of consensus can be demonstrated across the EU in the variety of risk assessment tools for human health and ecological risk-based soil quality assessments which have been found to vary widely and produce very different outcomes (*84, 85*). The multiple and often conflicting functions that are required of soil have slowed development of an acceptable method for evaluation of soil quality.

As many of the barriers in this policy area are associated with costs, there has been a call for development of screening tools to aid in identification of risk or priority areas for soils using indicators that are independent of soils function (*62*). Such methods can provide an efficient means of selecting areas of soil protection, in accordance with emerging soil protection legislation. This risk-based screening approach is in line with the move toward cost-effective decision making in environmental applications, including use of such methods in assessment of surface water status.

Function-independent indicators are such that they apply to cross functional parameters of quality, selected to be cost and labor effective to collect. Rather than giving definite values for each of the criteria, this approach could act as a screening step to inform further more detailed analysis. Such tools should be conservative in nature, with new information delivered, and used on their own or with existing data sets to provide additional evidence.

Inclusion of ecological status has been seen in environmental decision making as a key concept. Ecological risk assessment (ERA) is the evaluation of the potential significance of impacts in regard to likely effects upon ecological receptors as the result of exposure to a stressor (*86, 87*). In the USA the ERA framework consists of three major phases (problem formulation, analysis, and risk characterization) (*88*). Within the EU ecological receptors are considered in many countries soil quality standards; however, there is notable variation in ERA tools and the resulting soil quality standards between member states (*85, 89*). There is potential for harmonization of tools across the EU where the differences are scientific or technical and not due to geographical, cultural differences, or political choices (*85*).

There is scope for assessment of soils using function independent indicators in line with emerging policies, where there is likely to be a requirement to identify soil risk or priority areas (*62*). Developing the framework for assessment in accordance with the EU WFD, using a method that emphasizes the importance of the ecological value of soils could indicate areas for further attention. Inclusion of ecological protection targets have been seen in existing priority systems (e.g., Netherlands) and have the potential to be used as a screening method. The ecological status assessment framework used in the WFD can be adapted to meet the needs of soil quality assessment. However hydromorphological quality in the WFD refers to the hydrological and geomorphological elements and processes of water body systems' (*90*) and is not applicable to assessment of soil. Elements to assess the quality are about more than just 'chemical soil quality', they embrace every theme related to soil and can be modified slightly to look at biological, chemical, physiochemical, and morphological status. Hydromorphological quality used in the EU WFD can be replaced with morphological status, referring to the geological and geomorphology elements and processes of soil systems.

The DPSIR (Driver, Pressure, State, Impact, Response) approach is commonly used to assess the pressures and risk of failing objectives (*91*−*93*). Borja (*94*) uses the DPSIR approach to assess the pressures and risk of failing the objectives of the WFD. Threats included in the EU Soil Thematic Strategy can be related to soil indicators, allowing an adaption of the method applied to the WFD to be used to evaluate the risk of soils failing to meet the classification required of them by future legislation. The thematic strategy identified, using the DPSIR framework, a number of degradation processes or threats including erosion, decline in organic matter, local and diffuse contamination, sealing, compaction, decline in biodiversity, salinization, floods, and landslides, and indicators can be related to these threats (*8, 95*). The evaluation of the state and impact can be related to the affected system in classical risk assessment (*91*).

Evaluation of the state of and impact to soils using function independent indicators could allow a fundamental understanding of the soil system. This would have the potential to allow cost efficient targeting of resources to areas at highest risk of degradation. Integration of contaminated soils with other threats to soils into a common policy framework could minimize the risk of managing one soil threat while increasing the extent of another, effectively preventing trading off of one soil degradation process with another. Likewise, integrated management of environmental media has the potential to minimize the protection of one resource at the expense of another. By aligning soil protection policy with that of other environmental media, the potential to further develop integrated environmental quality management policies and mechanisms exists.

Harmonization of management frameworks for air, water, and soil is important for evaluation and protection of the environment. Increased understanding of relationships between environmental media has created the need to move from fragmented management of individual media toward integrated environmental quality management allowing protection of the environment as a whole rather than management of issues shifting the problem from one environmental media to another.

Acknowledgments

The authors wish to acknowledge the Engineering and Physical Sciences Research Council (EPSRC) for a Ph.D. studentship and the Big Lottery Fund UK for funding the OPAL Soil Centre that facilitated the collaboration between the authors of this work.

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ES101463Y