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Environmental monitoring, assessment and reporting

Guidelines for developing national strategies to use soil contamination monitoring as an environmental policy tool

Prepared by the Working Group on Environmental Monitoring and Assessment

Summary

The terms of reference of the Working Group on Environmental Monitoring and Assessment for 2012–2014 (ECE/CEP/2012/2, para. 48) call for it to give priority, inter alia, to strengthening monitoring of specific environmental media (ECE/CEP/2012/6, annex, para. 3 (c)). In pursuance of that mandate, the secretariat, with the assistance of a consultant, prepared draft guidelines for developing national strategies to use soil contamination monitoring as an environmental policy tool (ECE/CEP/AC.10/2013/6), which were submitted to the Working Group for consideration. The Working Group considered the guidelines at is fourteenth session (Geneva, 7–8 November 2013) and made some revisions.

The present document, containing guidelines as revised by the Working Group, is being submitted to the Committee on Environmental Policy at its twentieth session for consideration and adoption.

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Contents

I. General introduction

1. These guidelines aim to provide guidance to the countries of Eastern and South-Eastern Europe, the Caucasus and Central Asia (the target countries) in revising their local and diffuse soil contamination monitoring programmes and making monitoring a practical tool for environmental policy, especially for target setting, the development of environmental management strategies and assessing progress in achieving policy targets and the effectiveness of environmental management measures.

2. Protection of soil resources is strategically important because they support the supply of a wide range of services and goods necessary for maintaining the quality of life of citizens and for the conservation of biodiversity. Contamination of soil by toxic substances can affect the supply and quality of these soil-supported services and goods. Locally, high levels of soil contamination commonly arise from the historic and present misuse, disposal and spillage of waste materials, and may present a risk of harm especially to humans and water resources. Diffuse soil contamination over wide areas, generally at lower levels than local soil contamination, may present risks of chronic harm to the soil system itself, human populations, water resources and biodiversity.

3. Monitoring local and diffuse soil contamination requires different approaches and these are considered separately in this document.

4. Local soil contamination is confined to particular sites. The policy challenge is to assess the risks arising from these sites and, where this is above acceptable levels, to optimize their management. The approach to monitoring local soil contamination is based on establishing an inventory of contaminated sites, categorized by the stage they have reached in the risk assessment and management process and by the origins and types of contamination they contain.

5. Diffuse soil contamination is widespread. It results from general contamination of other environmental compartments, such as air and water, as well as the use of chemicals on land and the spreading of organic and other wastes. The policy challenge is to assess the levels of existing diffuse soil contamination and the effectiveness of policy aimed at controlling sources of this contamination. The approach to establishing a monitoring system for diffuse soil contamination is based on representative sampling of the general soil environment over large areas, followed by testing of samples for contaminants.

II. Local soil contamination monitoring

6. To minimize the negative effects of local soil contamination on public health and the environment, those target countries that have not yet done so should develop strategies to deal with sites where local soil contamination presents an unacceptable risk of harm to human health or the environment, including to: humans within residential housing, commercial premises or public spaces; surface waters and groundwaters; agricultural production; building structures; and biodiversity. Within such strategies, and set in an appropriate policy and scientific context, a fit-for-purpose approach should be developed to monitor the number, status, extent and characteristics of local soil contamination sites.

7. Local soil contamination is common, but confined to specific sites where industrial, commercial or other activities have created or continue to create sources of contaminants that present a potential risk. The identification and characterization of these sites is often complex and expensive, and developing a national inventory may take many years. Nonetheless, such an inventory is the foundation for understanding the nature and extent of local soil contamination to inform relevant policy, setting of priorities and targets and the preparation and assessment of particular policy instruments and measures.

8. The monitoring system should provide information on the extent and nature of local soil contamination to inform a strategy for dealing with it, for example, by identifying the locations and types of the most serious contamination for which available resources should be prioritized. Then, monitoring should inform the evaluation of current systems for managing local soil contamination and assist in identifying where changes can be made to improve their efficiency and effectiveness.

9. Monitoring should distinguish between sites that have been identified as presenting potentially unacceptable risks and those where investigations have been made to confirm or discount this risk. For those sites where an unacceptable risk has been confirmed, the monitoring of progress with their management should identify the number of sites for which a remediation strategy has been implemented to reduce risks to acceptable levels. In addition, information about the costs incurred and anticipated for risk management is valuable for budgeting and planning purposes.

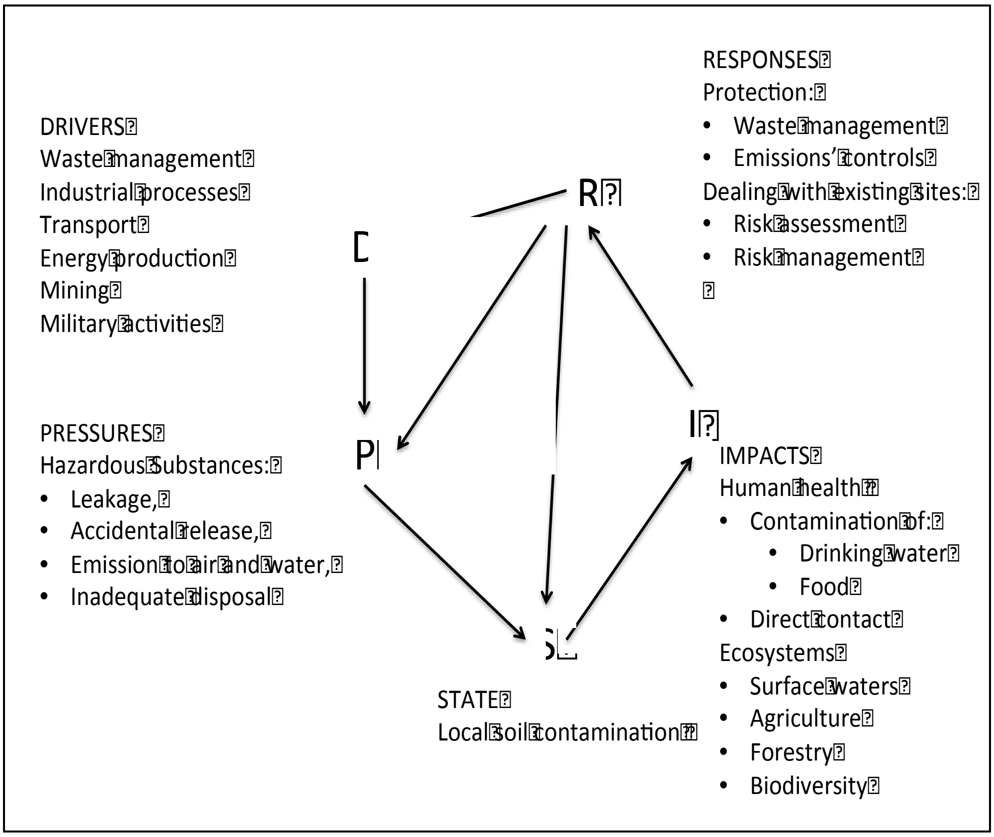
10. Figure 1 is an exploration of how local soil contamination relates to other areas of policy and regulation and how monitoring of local soil contamination may inform and be informed by other monitoring initiatives.[1] It uses a framework adopted by the European Environment Agency.[2] It relates "**D**rivers", represented by economic and other activities, to "**P**ressures", such as emissions of hazardous substances, that alter the "**S**tate" of soil and so have "**I**mpacts" on receptors that lead to management "**R**esponses".

11. The management of local soil contamination sites involves issues of spatial planning and economic development, as well as public health and environmental quality. The cost of dealing with local soil contamination that has accumulated over decades or even centuries can be very large and may not be completely affordable by current communities. Therefore it is essential to take a strategic approach when developing policy for the management of such sites, ensuring that this provides a clear framework for prioritizing the assessment and management of sites, taking account of national, regional and local economic, social and environmental objectives, as well as the availability of resources.

1 Lieve Van-Camp and others, "Contamination and land management", Reports of the Technical Working Groups Established under the Thematic Strategy for Soil Protection, vol. 4 (EUR 21319 EN/4) (Luxembourg: Office of the Official Publications of the European Communities, 2004).

2 Edith Smeets and Rob Weterings (eds.), "Environmental Indicators: Typology and overview", Technical Report No. 25/1999 (Copenhagen: European Environment Agency, 1999). See also S. Huber and others, "Environmental Assessment of Soil for Monitoring — Volume 1: Indicators & Criteria", Joint Research Centre Scientific and Technical Reports (Luxembourg: Office for Official Publications of the European Communities, 2009.

Figure 1
Relationships between sources of local soil contamination, their impacts and management responses



Source: L. Van-Camp and others (2004).

12. The appropriate governance of local soil contamination will vary depending on prevailing political structures, ideologies and political, social and cultural values. Monitoring of local soil contamination informs the process of governance, including operation of a legal framework. Over recent decades, those developed countries with a long history of industrial activity have evolved mature regimes for managing such sites. Their experience provides a useful opportunity for policy transfer to those countries with less mature regimes.[3] Table 1 illustrates key actors and their activities within an effective governance regime for local soil contamination.

[3] For example, see: Qishi Luo, Philip Catney and David Lerner, "Risk-based management of contaminated land in the UK: Lessons for China?", *Journal of Environmental Management*, vol. 90 No. 2 (February 2009), pp. 1123–1134; and Xiaobo Zhao, *Developing an Appropriate Contaminated Land Regime in China: Lessons learned from the US and UK* (Heidelberg: Springer Verlag, 2013).

Table 1
Elements of a governance regime for management of local soil contamination

Actors	*Activities*	*Outputs (Examples)*
Central Government (responsible ministers and their officials)	Setting an overarching policy framework	Key policies, e.g.: – Avoid new contamination. – Risk-based approach, focusing resources on higher risk sites. – Polluter pays principle applies, but with financial and legal incentives to encourage site assessment and management. – Local-level regulation to encourage integrated actions by landowners/managers/developers and regulatory authorities.
Legislature	Designing and enacting a national legislative regime	Legislation and statutory regulations, e.g.: – Legal definitions (e.g., of "Contaminated Site"). – Responsibilities. – Liability.
Central agency (e.g., Environmental Protection Agency)	Developing and maintaining technical guidance; monitoring progress	Regulatory and technical procedures for assessing and managing local soil contamination sites. Definition and publication of intervention values for contaminants. Technical expertise for "difficult" sites. Operation of national monitoring system for local soil contamination.
Landowners/managers/ developers; regional/ municipality departments for development control (spatial planning) and environmental protection; technical experts and specialized contractors; citizens and stakeholder organizations	Identifying sites; assessing risks; defining site management plans (according to regulations defined by central agency)	Systematic identification of possible sites of unacceptable local soil contamination. Preliminary studies/preliminary investigations of candidate sites. Main investigations of sites where required. Designation of sites as "contaminated land" (by regional/ municipal authorities).
	Implementing and signing-off on site remediation plans and execution (according to regulations defined by central agency)	Evaluating options for management of contaminated sites and agreeing detailed plans. Completing and confirming success of site plans.

A. Linking local soil contamination monitoring to environmental policy development

1. Definition of unacceptable local soil contamination and its implications for the environment and public health

13. The definition of unacceptable local soil contamination is fundamental to policy for dealing with local soil contamination.

14. There is no internationally agreed definition of unacceptable local soil contamination. Countries are recommended to adopt a definition that is risk and not hazard based,[4] meaning that the presence of a hazardous contaminant at any level does not in itself indicate unacceptable contamination, but instead acceptability should be assessed in relation to the magnitude of risk of harm to specific receptors (e.g., humans, natural waters, ecosystems). The advantage of a risk-based over a hazard-based approach is that it allows site-specific decision-making and avoids land being designated as having unacceptable local soil contamination because of the mere presence of contamination, when there is no unacceptable risk arising under its current or planned use. It should be noted, however, that site-specific risk assessment is more technically demanding than the simple use of hazard concentration thresholds and generally incurs higher management and technical investigation costs.

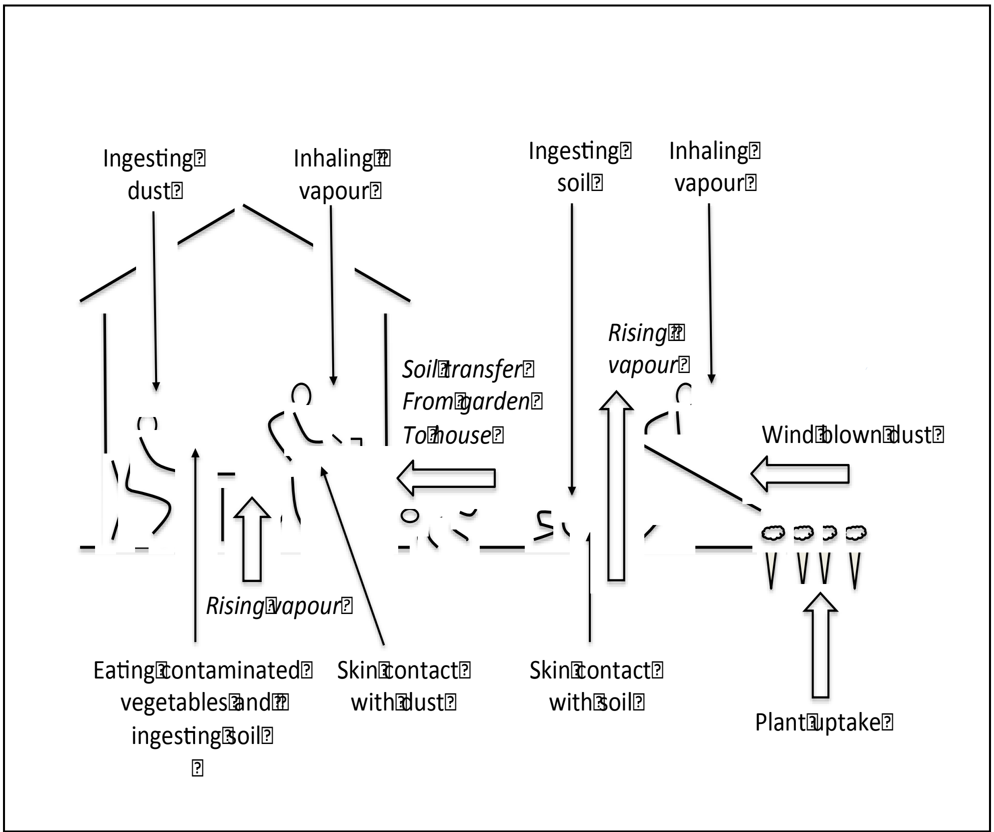
15. A receptor is only at risk of harm from local soil contamination if it is exposed to the contaminant(s). Risk of harm only exists when there is a viable **pathway** between the local soil contamination (the **source** of contamination) and the **receptor**. This pathway may take many forms, including contaminant transfer via water and air or direct contact or ingestion. To identify and estimate exposure, a conceptual model should be developed that identifies all possible pathways for contaminant(s) to transfer from the source to the receptor. Figure 2 provides an illustration of a generic conceptual model for human exposure to contaminants in homes with residential gardens.

16. To estimate the risk of harm to a receptor, the rate of mass transfer of contaminant through each identified pathway to the receptor has to be estimated and the sum of these rates calculated, preferably with an estimate of uncertainty. Then the impact of the total exposure on the receptor can be assessed and compared with a threshold for unacceptable risk of harm. A phased approach can be used to avoid a wasteful deployment of resources (see table 2). A preliminary study is made to identify potential sources of contaminants in soil and the receptors that may be harmed by the contaminants, and to formulate a conceptual model identifying potential exposure pathways. Where there are potential pathways, a preliminary site survey is made to quantify sources, confirm viable linkages and validate the conceptual model. A tiered main investigation follows: in the first tier, generic intervention or "screening" values may be used to assess if the risk is negligible, if these are available. These are concentrations of contaminants in soil that represent a precautionary level of unacceptable risk to receptors within a defined land-use scenario. Thresholds for unacceptable contamination vary depending on the present or intended future land use, as different linkages and rates of mass transfer of contaminants occur under different land uses, which therefore require the application of different conceptual models. Care is needed to ensure that the conceptual model assumed in the development of any

[4] Colin Ferguson and others (eds.), *Risk Assessment for Contaminated Sites in Europe*, vol. 1. *Scientific Basis* (Nottingham: LQM Press, 1998).

generic values being used both properly and completely represents the contaminant pathways at site being investigated.[5,6]

Figure 2
Representation of a generic conceptual model for human exposure to local soil contamination within a residential with gardens scenario



Source: Adapted from J. Jeffries and I. Martin, “Updated technical background to the CLEA model”, Science report SC050021/SR3 (Bristol: Environment Agency, 2009).

17. The definition of thresholds of unacceptable risk of harm requires the definition of both unacceptable harm and an unacceptable probability of exceeding this harm. This is achieved in four steps: (a) identification of the subject that is at risk of harm (the receptor); (b) identification of the type of harm that may be caused by exposure of the receptor; (c) definition of a quantitative measure of risk of this harm; and (c) definition of the unacceptable level of risk of harm.

18. For example, the risk of harm to human health from a contaminant X could be assessed in relation to the risk of harm to a 6-year-old female child (chosen as the most sensitive receptor type). The type of harm that may result from exposure to contaminant X could be disease Y, and the measure of risk of harm could be the lifetime chance of such a child contracting Y, relative to that for the wider population of non-exposed children. A

5 Simon Cole and Jo Jefferies, “Using Soil Guideline Values”, Better Regulation Science Programme, Science report SC050021/SGV (Bristol: Environment Agency, 2009).
6 United States Environmental Protection Agency, “Soil Screening Guidance: User’s Guide”, 2nd ed. (Washington, D.C., Office of Emergency and Remedial Response, 1996).

policy decision might be made that any increment in the incidence of the disease above 1 in 100,000 of the population is unacceptable.

19. To define an unacceptable level of soil contamination corresponding to a defined level of unacceptable harm, the extent of exposure has to be related to the resulting magnitude of risk of harm. This requires a quantitative dose-response relationship between the exposure level and risk of harm and an estimate of exposure based on a modelled transfer of contaminant through the pathways identified in the conceptual model for the site (or model site if deriving generic thresholds).

20. It will be clear that the process for defining unacceptable levels of local soil contamination requires considerable technical expertise in site description, exposure modelling and toxicology. Moreover, the evidence base for the process is often incomplete or uncertain so that “expert judgment” has to be applied, which may be contested. Therefore, countries should ensure that they maintain or develop relevant institutional capacities through education, training and practice.

21. When evaluating risks from local soil contamination to public health and/or the environment (from, e.g., uptake of contaminants in to the food chain or dispersion of contaminated soil as airborne dust or contaminant transfer to natural waters) account should be taken of other sources of similar risk (e.g., human exposure to contaminants from imported food and local air pollution, contributions to poor surface water quality from current industrial discharges, etc.). To most efficiently reduce the overall risk of harm to an acceptable level, an integrated approach should be taken to deciding which sources of contamination (including but not confined to local soil contamination) should be the priorities for controls and management.

22. It is stressed that the decision about what presents unacceptable risk is a societal and not a scientific one; scientific characterization of risk is essential for, but can only inform, policy on unacceptable risk. Acceptable levels of risk of harm to receptors will be informed by general policy concerning these receptors. For example, thresholds for risk of harm to humans from local soil contamination should be informed by public health policy targets and be consistent with the levels of risk implied by existing standards for air, water and food quality. Similarly, thresholds for acceptable soil contamination to control risk of harm to environmental quality, e.g., of surface waters and groundwaters, should be informed by the quality targets for these environmental compartments.

23. Table 2 provides a summary of some generic threshold values. Differences in the definition of these values in different countries are likely to reflect a range of factors, including: uncertainty in and different interpretations of toxicological data; in-country harmonization of thresholds for different environmental compartments, e.g., of acceptable human intake from air, water and food as well as soil, as defined by ministries of public health; and differences between countries in policy-defined acceptability of risk of harm to humans and other receptors. Sites where generic values are exceeded are normally classed as potentially contaminated and, in this case, or where generic values are not available for the particular contaminant or land use being considered, a second-tier risk assessment is applied to develop site-specific modelling of exposure and receptor responses and compare these with acceptable levels. Where unacceptable levels of risk are confirmed, the site may be designated a “contaminated site”.

Table 2
Comparison of country-specific risk-based screening levels (mg kg-1 dry weight)

	Australia/ New Zealand	*Canada*	*China*	*Hong Kong (urban)*	*Netherlands*	*Thailand*	*United Kingdom*	*United States of America*
Metals								
Arsenic	100	12	20	22	55	4	32	0.4
Chromium VI	100	0.4		221		300		0.3
Lead	300	140	140	248	255	530		400
Hydrocarbons								
Benzene	1.1	0.007	0.2	0.7	1	6.5	0.33	1.1
Toluene	68	0.08	26	1 440	130	520	610	5 000
Ethyl-benzene	48	0.018	10	709	50	230	350	5.4
Xylenes	48	2.4	5	95	25	210	230	630
Methyl-t-butyl ether				6.9	100			43
Persistent organic pollutants (POPs)								
Total dioxins and furans	$4x10^{-6}$			$1x10^{-3}$	$1x10^{-3}$		$8x10^{-3}$[a]	$4.5x10^{-6}$[b]
Aldrin			0.04		4[c]			0.029
Dichlorodiphenyl-trichloroethane (DDT)		0.7	1		4[d]	17		1.7
Total Polychlorinated biphenyls (PCBs)	10	1.3	0.2	0.236	1	2.2		0.22
Chlorinated solvents								
Trichloroethene		0.01	12	0.523	60	28		2.8
Tetrachloroethene		0.2	4	0.10	4	57		0.55
Vinyl chloride					0.1	1.5		0.06

Source: Amy Quintin and Lucy Fraiser, "Comparison of International Risk-based Screening Levels", *Proceedings of the Annual International Conference on Soils, Sediments, Water and Energy*, vol. 15, Article 24 (2010).

[a] Total of dioxin- and furan-like compounds.
[b] Level for 2, 3, 7, 8 tetrachloro-dibenzodioxin.
[c] Sum of aldrin, endrin and dieldrin.
[d] Sum of DDT, dichlorodiphenyldichloroethylene (DDE) and dichlorodiphenyldichloroethane (DDD).

2. Monitoring the extent of and progress in management of local soil contamination

24. The management of local soil contamination sites[7] follows a sequential pattern of risk assessment and risk management. Each of these steps is made up of a set of connected

[7] Environment Agency, "Model Procedures for the Management of Land Contamination", Contaminated Land Report 11 (Bristol, 2004).

decisions and actions. Risk assessment describes and evaluates the risk presented by a site and determines whether or not action is required to deal with unacceptable risk. Risk management involves identifying possible options for dealing with unacceptable risk, selecting the most appropriate one to define a remediation strategy and implementing it.

Table 3
Steps in the management of local soil contamination

Step	*Stage*	*Description*	*Metric for monitoring*
Risk assessment	Preliminary study	A mainly desk-based development of a site conceptual model to determine if there is a possibility of receptor exposure leading to unacceptable risks from local soil contamination.	Number of sites with preliminary studies in progress
	Preliminary investigation	Quantitative risk assessment (using generic screening values) of sites identified in preliminary studies as having viable source-receptor pathways, to determine if they are "potentially contaminated sites", i.e., they are potentially contaminated to an unacceptable level.	Number of potentially contaminated sites
	Main investigation	Detailed non-generic quantitative risk assessment of sites identified as potentially contaminated sites to confirm or otherwise that levels of soil contamination present unacceptable risk of harm to specified receptors and therefore whether the sites are "contaminated sites".	Number of contaminated sites
Risk management	Options appraisal	Options appraisal and definition of a remediation strategy for contaminated sites (options[a] could include excavation and off-site disposal, ex-situ or in-situ remediation, containment, restricting future use or monitoring).	
	Implementation of remediation strategy	Detailed design, implementation and verification of remedial works.	Number of sites where a remediation strategy is being implemented

[a] United Nations Economic Commission for Europe, *Compendium of Soil Clean-up Technologies and Soil Remediation Companies*, 2nd ed. (Geneva, 2000).

25. The central purpose of a monitoring system for local soil contamination is to address the key questions:

What is the estimated extent of local soil contamination?

How much progress is being achieved in the management and control of local soil contamination?

26. Therefore monitoring should provide data on:

(a) The number of sites where possible or confirmed contamination is being managed;

(b) The stage that the management of individual sites has reached.

27. The extent of local soil contamination and progress with its management can be evaluated by monitoring the number of sites at each step and the percentages of all sites at each step. The main steps in the management of sites with local soil contamination and the metrics for monitoring the number and status of these sites are detailed in table 3 and align with those identified in the most recent European data collection exercise.[8]

28. The key message is that meaningful monitoring of local soil contamination requires an agreed definition of unacceptable contamination to define “contaminated sites”. This is particularly relevant to international comparisons because different countries have developed different definitions of contaminated land within their legal frameworks. A related issue arises in relation to the size (area) of sites, as some countries may designate only the areas of more highly contaminated sites occurring in clusters within a wider area while others designate the whole area of clusters. This emphasizes the importance of exact and transparent national definitions.

3. Monitoring the origins of local soil contamination

29. Information about the origin of local soil contamination is useful when developing priorities for deployment of resources because different historic and current activities give rise to different types of contamination with varying risk profiles. Data on the origin of contamination on sites of local soil contamination is valuable when answering the question:

Which sectors contribute most to local soil contamination?

30. Activities that have commonly caused local soil contamination are waste disposal, industrial and commercial activities (mining, chemical manufacture, oil extraction and refining, etc.), military activities (e.g., contamination arising from warfare as well as peace-time operations); storage (oil and oil products, chemicals, etc.); transport (via spillage); and nuclear operations. Many sites have a history of contamination arising from different activities that have occurred at different times, and in these cases data on the dominant origins of the contamination may be sufficient for planning purposes.

4. Monitoring of the types of local soil contamination

31. As the risk of harm to receptors is contaminant-specific, information about which contaminants are present on sites is important for policy development. Different groups of contaminants are associated with different sectors as in table 4. Data should be collected on the actual types of contaminants that have been identified for sites to answer the question:

What are the main contaminants affecting soil and groundwater in and around local soil contamination sites?

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[8] Marc Van Liedekerke and others, “Progress in the Management of Contaminated Sites in Europe” (Luxembourg: Office of the Official Publications of the European Communities, 2013) (forthcoming).

Table 4
Some current or historic activities associated with local soil contamination[9]

Activity	*Possible contaminants (examples only)*
Airports (civil and military)	Hydrocarbons
Asbestos manufacturing	Asbestos
Ceramics, cement and asphalt manufacture and use	Asbestos, metals, hydrocarbons, POPs
Chemical works and use: – Coating and paints – Cosmetics and toiletries – Disinfectants – Explosives and propellants – Fertilizers – Fine chemicals – Inorganic chemicals – Organic chemicals – Floor covering materials – Sealants and adhesives – Pesticides – Pharmaceuticals – Rubber – Soaps and detergents	Metals, hydrocarbons, POPs, chlorinated solvents
Dockyards	Metals, hydrocarbons
Engineering works (e.g., manufacturing): – Aircraft – Electrical and electronic equipment – Mechanical – Armaments – Motor vehicles – Ships	Metals, hydrocarbons, POPs, chlorinated solvents
Gas, coke and carbonized coal works	Metals, hydrocarbons, POPs, cyanide
Non-ferrous metals works	Metals

9 For detailed profiles, see http://www.environment-agency.gov.uk/research/planning/33708.aspx.

Activity	*Possible contaminants (examples only)*
Precious metal refining	Metals
Oil refining and oil storage	Hydrocarbons, POPs
Power stations	Hydrocarbons, POPs
Railway operations	Hydrocarbons, POPs, chlorinated solvents
Road vehicle fuelling, servicing and repair (including road transport operations)	Hydrocarbons
Wastewater treatment	Metals

5. The resources deployed for the management of local soil contamination

32. In general, when dealing with sites of local soil contamination, the cost of each stage increases progressively from the preliminary study, to the preliminary investigation, to the main investigation, to the implementation of a remediation strategy. Data on the expenditure being incurred at sites at each stage can provide information about present and likely future costs and assist budget development by answering the question:

What are the costs of managing local soil contamination sites?

33. This data can also be used to benchmark in-country costs per site with those reported by other countries dealing with similar sites.

6. Metrics and targets for management of local soil contamination

34. The complexity of local soil contamination sites and the extensive resources needed to deal with them should not be underestimated when setting management targets. Initial targets should not be overly ambitious and the aim should be to focus on reporting progress with identifying and then assessing and managing those sites that are likely to present the highest risks.

35. Targets should relate to policy objectives and be measurable. For example, the objective may be to progressively reduce the risk from contaminated sites to an acceptable level under their current land use. In this case, and only as illustration, possible targets might be as follows:

(a) Preliminary studies and investigations for 80% of all identified sites to determine if they are potentially contaminated (completed within 10 years of the baseline year);

(b) Main investigations of 50% of potentially contaminated sites to determine if they are contaminated sites (completed within 15 years of the baseline year);

(c) Remediation strategies followed by their completed implementation for 30% of contaminated sites (completed within 20 years of the baseline year).

36. A baseline survey is needed to inform the selection of workable targets for remediating local soil contamination sites. Meaningful and achievable quantitative targets require reliable information about the anticipated number and type of sites, as well as the realistic rate at which they can be improved. Therefore target setting and refinement should be done iteratively as data collection proceeds and better information becomes available on the number and nature of sites and the costs of dealing with them.

37. The metrics set out in box 1 align closely with those used in the definition of the European Environment Agency CSI015 indicator,[10] Progress in the Management of Contaminated Sites. Box 1 provides a "core" list of metrics linked to this indicator for which targets can be set and data collected.

38. Where data is also collected on the origins and types of local soil contamination, the metrics listed in box 1 can be analysed by origin (e.g., the extent of local soil contamination associated with mining, manufacturing, etc., as well as progress in its management) or type (e.g., the extent of metal contamination, as well as progress in its management).

[10] Gundula Prokop (ed.), "Second technical workshop on contaminated sites: Workshop proceedings and overview", Technical Report No. 76/2002 (Copenhagen: European Environment Agency, 2002).

Box 1

A core set of metrics for monitoring of local soil contamination

- Total number of sites undergoing risk assessment or risk management (i.e., all sites within inventories)
- Number of sites with preliminary studies in progress
- Percentage of total number of sites with preliminary studies in progress
- Number of potentially contaminated Sites
- Percentage of the total number sites currently identified as potentially contaminated sites
- Number of contaminated sites
- Percentage of the total number sites identified as contaminated sites
- Number of sites where a remediation strategy is being implemented
- Percentage of the total number of sites where a remediation strategy is being implemented
- Number of sites incurring costs within expenditure categories

39. Experience[11] indicates that it is better to focus on the number of sites at each step at a point in time than to attempt to construct a "mass flow" of sites between successive data collection exercises — i.e., to track the progress of individual local soil contamination sites from one exercise to the next. This is because as sites progress through risk assessment to the implementation of remediation strategies, some are eliminated while other are redefined, depending on available information over time and also due to changing regulatory definitions of contaminated sites. As a result of such changes the total number of sites and their allocation to the different management steps may not be consistently reported.

B. Modernizing and upgrading national systems for local soil contamination monitoring

1. Organization and resources

40. Monitoring of local soil contamination requires two types of activity:

(a) Central planning, coordination, reporting and archiving of data collection exercises;

(b) Local collection of data.

41. It is recommended that a single national institution coordinates local soil monitoring and related data collection in the country. This should include the power to specify data requirements and management, including regarding data collection, validation, reporting and archiving. It should be made responsible for planning and coordinating all data collection exercises, maintaining country databases (inventories) and country reporting.

[11] Marc van Liedekerke and others, "Progress in the Management of Contaminated Sites in Europe".

42. In principle, data could be collected and collated at any administrative level (e.g., municipality, region, country); in practice, data collection at a regional level is likely to offer the best compromise between ensuring that information is specific enough to an area to be useful while avoiding the excessive costs that may occur from collection at the local level.

43. Planning, coordination, reporting and archiving by a central agency requires a secretariat. Depending on the overall density of sites and the frequency of reporting, each data collection exercise could require between one and three person years of effort.

2. Data requirements

44. The minimum requirement is for data to be collected at regular intervals for the metrics listed in box 1.

45. In addition, to provide information about the extent of local soil contamination, it is recommended that data is collected on the:

(a) Size (areas) of sites at the different stages;

(b) Number of sites where contamination has arisen from the activities of economic sectors;

(c) Number of sites with particular types of contamination;

(d) Costs incurred for sites at each step.

3. Frequency of data collection

46. Progress in the identification and management of local soil contamination sites typically takes a number of years and data collection exercises with a frequency of less than five years may not identify meaningful changes. Consideration should be given to harmonizing exercise timing and reporting with others exercises, e.g., with national or international state-of-the-environment reporting.

4. Data collection, quality assurance and management

47. Data collection should make use of a structured questionnaire with unambiguous questions supported by a precise definition of reporting units. Consistent and comparable information over time can only be obtained if the questionnaire is not changed between exercises, or at least the original questions are retained even if others are added. Therefore it is important to invest effort in the development and quality assurance of the initial questionnaire, including by undertaking pilot exercises with draft questionnaires and careful consideration of feedback from a representative group of those who complete them. Options for web-based reporting should be explored and used where these offer greater efficiency and opportunities for quality assurance. It is useful to provide a "help desk" service to answer queries, as this will assist the return of fully completed questionnaires and help ensure optimum accuracy of data entry.

5. Reporting

48. In addition to data and its analysis, reports should provide a full explanation of the definitions, units used, the policy context and the purpose of the monitoring system.

49. The most recent report on progress in the management of contaminated sites in Europe[12] provides a complete example of data reporting on local soil contamination sites. It also provides information about the costs of managing local soil contamination in the countries reporting data.

C. Summary of key points

50. A strategy for dealing with sites of local soil contamination requires:

(a) A policy-determined definition of "contaminated sites" that present unacceptable risks;

(b) A scheme for prioritizing available resources to deal with those sites presenting most risk to humans, surface waters, groundwaters and ecosystems;

(c) Targets to assess and drive progress.

51. The process of managing sites of local soil contamination is stepwise and includes: preliminary studies; preliminary investigations; main investigations; options' appraisals; and implementation of remediation strategies. Targets for progress in dealing with sites of local soil contamination should relate to the completion of these steps in the management process.

52. An efficient monitoring system for assessing progress in dealing with sites of local soil contamination requires:

(a) Designation of a single institution for its development and maintenance;

(b) A central inventory of local soil contamination with data on:

(i) Sites under preliminary studies;

(ii) Potentially contaminated sites;

(iii) Contaminated sites;

(iv) Sites with agreed remediation strategies;

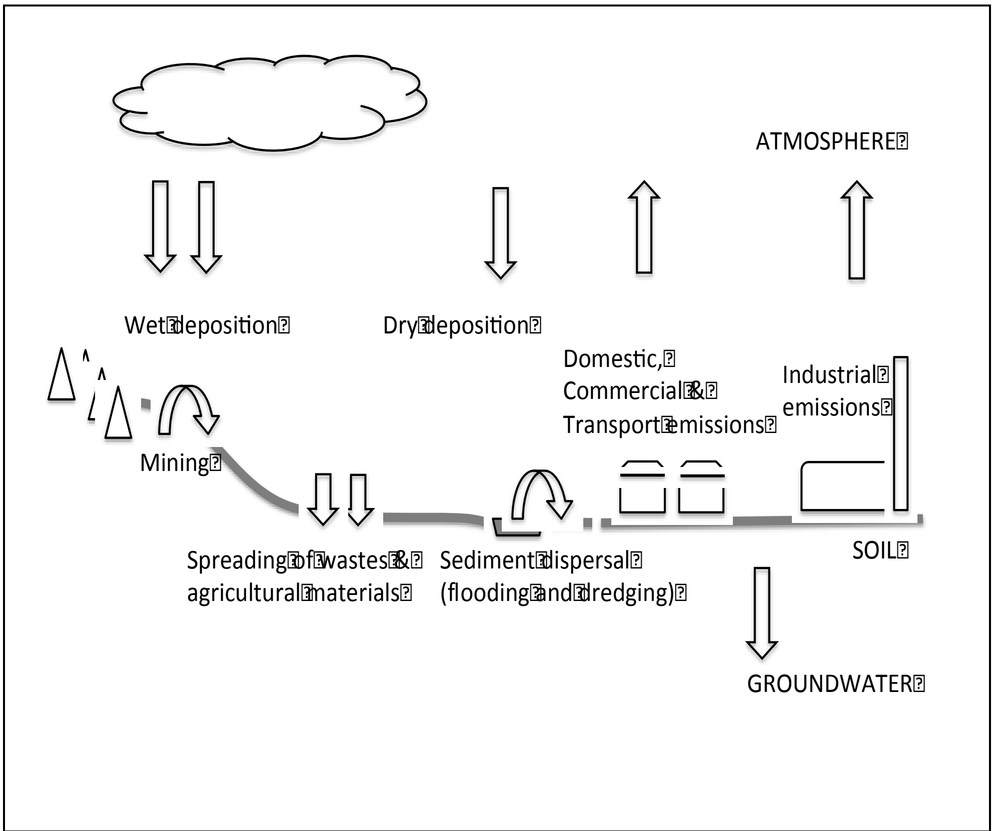
(c) Data collection exercises at intervals of no less than five years using a carefully developed and unchanging questionnaire.

III. Diffuse soil contamination monitoring

53. Diffuse soil contamination results from the dispersion of pollution from major point sources (e.g., long- and short-range dispersion of airborne emissions from industrial facilities, dispersal of contaminated waste by flooding), pollution from weaker sources that are widespread (vehicles, domestic heating, small-scale waste combustion, etc.) and land management operations that are polluting (e.g., spreading of waste materials that contain contaminants or agricultural spraying). Some contaminants are entirely or very substantially anthropogenic in origin (e.g., pesticides) whereas others may originate from anthropogenic sources but are also naturally present in soil (metals in minerals within soil parent materials, etc.).

[12] Ibid.

Figure 3
Sources of diffuse soil pollution



54. To minimize the possible negative effects of diffuse soil contamination on public health and the environment, those countries that have not yet done so should develop strategies to assess the current state of diffuse soil contamination in their territories to inform their management of this contamination. The nature of diffuse contamination is such that any effects it has on public health and ecosystems will tend to be subtle and chronic, and normally only discernible from observation of whole populations or the wider environment. This contrasts with local soil contamination where the relevant levels of contamination are higher and where unacceptable risks to individual receptors (e.g., residents, water bodies) may be identified more clearly. Preventing diffuse soil contamination is essential to avoid a permanent degradation of soil resources because in most cases it is not technically or economically feasible to remove this type of contamination.

55. A precautionary policy position is that diffuse soil contamination should be minimized where feasible and economics allow. An essential prerequisite for managing diffuse soil contamination is to have reliable and up-to-date information about its extent and trends in its levels. Therefore an efficient approach should be developed to implement monitoring of diffuse soil contamination as a basis for identifying, in particular, if this contamination may be or is becoming a hazard to food production and/or water quality and which types and locations of the contamination may be a priority for management.

56. A key message of this document is that monitoring of diffuse soil contamination should be integrated within an overall environmental assessment and management system

and should therefore be designed, developed and interpreted in broad policy and scientific contexts. Diffuse soil contamination is ubiquitous and its sources, both past and present, are many and various (see figure 3). Soil is a sink for diffuse contamination within the wider terrestrial environment and controlling this contamination requires a holistic approach that integrates relevant policy on the management of air quality, water quality, the specification and licensing of materials applied to soil and in agriculture and waste management. The institutions responsible for these different aspects of environmental management need to be consulted in the development of a monitoring system for diffuse soil contamination, to ensure it will meet their needs as users of outputs from the monitoring. However, the responsibility for establishing and maintaining a system for monitoring diffuse soil contamination should be set in a clearly defined institutional framework, with one central competent authority responsible for the coordination of all activities within the system.

A. Linking diffuse soil contamination monitoring to environmental policy development

1. Priority contaminants for environmental and public health policy

57. The range of diffuse inorganic and organic contaminants that could be monitored is extensive, and assessment of all of these is not realistic given the resources that are likely to be available to countries. Therefore a list of contaminants that are priorities for monitoring is required. This list should include particular contaminants that are hazardous and that are known to be present in soil of the monitored territories or whose presence is anticipated given past and/or continuing activities (contamination by particular metals as a legacy of mining and ore processing; known historic accidents and spillage, etc.). Table 5 provides an indicative list of potential priority contaminants that may provide a starting point for developing a country’s priority list. The extra costs of including additional contaminants may not be excessive, as a major part of the cost of soil monitoring is associated with soil sampling and as the marginal cost of additional laboratory testing of samples may be relatively low.

Table 5
Potential priority contaminants for monitoring diffuse soil pollution

Type of contaminant	*Examples (potential priority contaminants)*
Heavy metals	Cadmium (Cd), chromium (Cr), copper (Cu), lead (Pb), mercury (Hg), nickel (Ni), zinc (Zn)
Metalloids	Arsenic (As), Antimony (Sb), Selenium (Se)
Persistent Organic Pollutants (POPs)	Poly-chlorinated biphenyls PCBs, polycyclic aromatic hydrocarbons (PAHs), dioxins, furans, banned pesticides

2. Natural background contamination and its implications

58. Many inorganic diffuse soil contaminants occur naturally in soil; for these a crucial issue is the estimation of natural background levels so that incremental anthropogenic inputs can be estimated. An effective monitoring system should be capable of measuring background levels with reasonable confidence. Unbiased estimates of background levels

may be estimated[13] from the distribution of measured levels over the area of interest. Options are to identify a value that falls outside a set range, e.g., two standard deviations or two median absolute deviations below the mean level, or to select the tenth percentile value (see table 6). When possible, background levels should be estimated for different soil-forming materials (e.g., hard rock, sediments, glacial deposits), as their geochemical composition strongly influences natural background levels. It should be noted that background levels may exceed risk-based thresholds for local soil contamination where there is unfavourable geochemistry.

Table 6
Illustrative limits and ranges of diffuse contamination of soil by cadmium and lead

Land cover	*Soil-forming material*	*Metal*	*Mean +/- 2 standard deviations*	*Median +/- median absolute deviations*	*Tenth to ninetieth percentiles*
Urban	All	Cd	0.1–2.3	0.2–2.0	0.2–1.4
		Pb	11–370	17–210	28–140
Agriculture	Mudstone	Cd	0.3–1.9	0.4–1.5	0.4–1.4
		Pb	14–110	17–74	23–89
	Chalk till	Cd	0.2–1.3	0.2–1.1	0.3–1.0
		Pb	9–65	11–48	13–42
	Sandstone/ Mudstone/Shale	Cd	0.3–2.3	0.2–1.8	0.2–1.4
		Pb	14–320	18–220	28–240
Semi-natural/forest	Sandstone/ Mudstone/Shale	Cd	0.0–1.7	0.1–1.3	0.1–1.0
		Pb	19–500	29–350	36–260

Source: João Carreira, and others, "Pilot Area: England and Wales", in *Environmental Assessment of Soil for Monitoring*, vol. IVb, *Prototype Evaluation – Pilot Studies*, M. Stephens and others (eds.) (Luxembourg: Office for the Official Publications of the European Communities, 2008), pp. 177–187.

3. Setting thresholds and targets for diffuse soil contamination

59. The practical aim of monitoring diffuse soil contamination is to identify current levels and trends to identify where thresholds for acceptable contamination have been or are likely to be exceeded. An effective monitoring system will be capable of measuring whether these thresholds have been exceeded with acceptable confidence.

60. The acceptability of risk of harm arising from diffuse soil contamination depends on the land use and environmental context (e.g., agriculture or forestry); therefore different risk-based thresholds should ideally be applied to different current or anticipated land uses and in different landscapes. For example, higher levels of some contaminants (e.g., cadmium) will be more critical if the land is used for producing food, as they may be taken into the human food chain, compared with semi-natural forest land from which no food is harvested.

61. It is recommended that relevant risk-based thresholds are used where these are available and do not exceed background levels and that otherwise an empirical approach is applied to setting target levels. Risk-based thresholds for diffuse soil contamination are not

[13] International Organization for Standardization, ISO 19258:2005 — Soil Quality — Guidance on the Determination of Background Values.

agreed internationally and exist for a limited range of contaminants in a few jurisdictions. Countries may decide to set thresholds to protect food production for domestic consumption and/or export by estimating the uptake of contaminant in to crops for different levels of soil contamination and relating the estimated uptake to standards for food quality. An alternative approach is to use targets for contaminant levels based on a percentage or absolute increment of contamination over the estimated background level or on a particular percentile in the overall observed distribution of levels, e.g., the upper limit of the ninth decile (see table 6).

B. Modernizing and upgrading national monitoring systems for diffuse soil contamination

1. Organization and resources

62. Data collection and reporting at country level should be supported by a central technical facility for sampling and testing and for data analysis. This will ensure that a consistent approach is applied across the territory and in successive data collection exercises, and will provide the best opportunity for developing and maintaining databases and technical capacities.

63. The cost of establishing and maintaining a monitoring system for diffuse soil contamination will depend on the number of sampling sites and contaminants measured. The costs will include: (a) planning, coordination, collation, analysis and reporting of data by the coordinating centre; (b) sample collection; and (c) sample testing. As an approximate guide: a permanent dedicated team of between one and two persons may be required at the coordinating centre; sampling of each site will require from two to five person days; a basic suite of testing for metals might cost approximately $100 per sample, while the cost of testing for individual organic contaminants might range from $50 to $500 per sample.

2. Specification of measurement performance

64. The exact purpose of the monitoring system for diffuse soil contamination should be defined to inform the specification of data requirements in terms of the types and quality of data (measurement performance) required to meet end-user requirements. For example, one of the purposes might be to obtain national data on levels and trends in diffuse Pb soil contamination following the closure of lead works. In this case, the monitoring system would need to have sufficient power to be able to detect a policy-determined target for reduction in the rate of increase of the level of Pb contamination in soil within a targeted timescale with reasonable confidence. This requires a formal specification of the measurement performance required, including the required detection limit and precision for obtaining estimates of the rate of change in Pb levels in soil.

65. In general, it is recommended that the measurement specification for soil contaminants being targeted in a monitoring system should specify the:

(a) Absolute detection limit, i.e., the minimum level of the contaminant that can be detected (mg kg^{-1});

(b) Dynamic range over which measurement of levels of the contaminant are required (mg kg^{-1});

(c) Maximum error allowable, e.g., specified as the standard deviation of measurements of the level of contaminant at 80% of the dynamic range (mg kg^{-1});

(d) Detection limit for a change in the level of contaminant at, e.g., 50% of the dynamic range, over a specified period (mg $kg^{-1}y^{-1}$).

3. Establishing a monitoring system for diffuse soil contamination

66. The investment required to establish an operational monitoring system for diffuse soil contamination is substantial and will be wasted if it does not reach the required performance. Moreover, the actual performance cannot be confirmed until at least two sampling campaigns have been completed. Therefore it is very worthwhile to invest in a thorough investigation of the expected measurement performance of design options using statistical modelling before implementing a monitoring system. Practical considerations are also important: e.g., it may be desirable to make use of an established network of sampling points (for example, when there is an existing soil monitoring system for other types of soil degradation) and particularly if there are data on soil contamination from previous sampling exercises.

67. If a soil monitoring system is intended to support measurements of a range of unrelated contaminants, the ideal option for each of these will most probably be different and a compromise option will need to be chosen that optimizes the performance across all the monitored contaminants. Furthermore, formal statistical analysis of expected monitoring performance requires prior knowledge of the spatial, temporal and spatial-temporal variance in rates of change in contaminant levels, which may not be known or reliably estimated. An important consideration is that once a monitoring system is established for one set of contaminants, it may in the future need to be used to provide data for additional contaminants that were not anticipated at its inception.

68. Overall, it is recommended that target countries should establish monitoring systems for diffuse soil contamination that provide as good a capability to meet a range of current and potential future user needs as is achievable within available resources, adapting existing systems and sampling networks where possible and appropriate. A general scheme for achieving this is discussed below.

69. The power of soil monitoring systems, including those for diffuse soil contamination, depends especially on the spatial density and the temporal frequency of sampling, the spatial and temporal variation in the sampled area and the errors arising from sampling and measurement. The main options are a model approach that locates sampling sites, e.g., at the nodes of a regular grid, or a classical approach in which sites are selected randomly from within strata (categories of possible sampling sites) representative of different land use/cover, geology, etc. The latter approach is more suited to monitoring where there is an exactly defined objective that is not expected to change over time, e.g., to answer the question “Are there differences in diffuse soil contamination levels and trends between these land uses?” Its main disadvantage is that it is less easily adapted to address new questions, whereas sampling points can be re-categorized in a grid-based system to address new questions because the location of sites is independent of their nature.

70. On balance, it is recommended that countries establish systems based on regular grids as these are more flexible to meet future needs, although the measurement performance they provide for a given number of sites is likely to be somewhat less than randomized sampling within strata. A European-wide project to develop a continental-scale soil monitoring system (ENVASSO) recommended[14] a minimum sampling density of one site per 300 square kilometres. This density corresponds closely to that used by the International Cooperative Programme on Assessment and Monitoring of Air Pollution Effects on Forests, in which sampling points are located at nodes on a regular 16-kilometre

[14] Dominique Arrouays and others (eds.) *Environmental Assessment of Soil for Monitoring*, vol. IIa, *Inventory & Monitoring*. (Luxembourg: Office for the Official Publications of the European Communities, 2008).

grid.[15] Except for smaller countries, this sampling density and approach is likely to be adequate for most policy purposes and has the advantage of being capable of being harmonized with a continental-scale monitoring system.

71. It is recommended that successive sampling campaigns are held at intervals of about 10 years. Changes in local soil contamination at country scales are generally not measurable over shorter periods.

72. Large variations in levels of diffuse contamination of soils are observed at field scales (1–10 metres (m)) and it is essential to take account of this variation by sufficient subsampling of an adequately large area at each sample location. The ENVASSO project recommended that sampling areas be between 100 square metres (m^2) and 1 hectare and that between 10 and 100 subsamples be taken to a fixed depth (e.g., 0.15 m–0.30 m). This is the recommended practice. To avoid resampling positions within the sample location that have been sampled in previous campaigns, each sample location should be surveyed and a permanent grid of subsampling blocks delineated. Unless there is a particular requirement to estimate the within-sample location variation in contaminant levels it is recommended that subsamples are bulked up, carefully mixed and representative samples are taken of the bulk sample for laboratory or other testing.

73. It is recommended that samples are retained in a well-ordered and catalogued archive so that they can be tested for additional contaminants at a later date when needed and in case uncertainties in measurement data requiring their retesting.

74. Standard testing methods should be employed. Standard ISO methods[16] should be used for preparing samples for laboratory testing (see box 2) and for the required tests.

Box 2
International standards for sampling of soil

ISO 10381-1: 2002, Soil quality — Sampling — Part 1: Guidance on the design of sampling programmes

ISO 10381-2: 2002, Soil quality — Guidance on sampling techniques

ISO 23909: 2008, Soil quality — Preparation of laboratory samples from large samples

ISO 11465: 1993, Soil quality — Determination of dry matter and water content on a mass basis — Gravimetric method

ISO 18512: 2007, Soil quality — Guidance on long and short term storage of soil samples

ISO 12914:2012, Soil quality — Microwave-assisted extraction of the aqua regia soluble fraction for the determination of elements

ISO/TS 16965:2013, Soil quality — Determination of trace elements using inductively coupled plasma mass spectrometry (ICP-MS)

ISO 11047:1998, Soil quality — Determination of cadmium, chromium, cobalt, copper, lead, manganese, nickel and zinc — Flame and electrothermal atomic absorption spectrometric methods

[15] See http://icp-forests.net/page/largescale-forest-condition.
[16] Details of ISO Standards are available from http://www.iso.org/iso/home/store/catalogue_tc/catalogue_tc_browse.htm?commid=54328.

ISO 20280:2007, Soil quality — Determination of arsenic, antimony and selenium in aqua regia soil extracts with electrothermal or hydride-generation atomic absorption spectrometry

ISO 16772:2004, Soil quality — Determination of mercury in aqua regia soil extracts with cold-vapour atomic spectrometry or cold-vapour atomic fluorescence spectrometry

ISO 14507:2003, Soil quality — Pre-treatment of samples for determination of organic contaminants

ISO 13876:2013, Soil quality — Determination of polychlorinated biphenyls (PCB) by gas chromatography with mass selective detection (GC-MS) and gas chromatography with electron-capture detection (GC-ECD)

ISO 13914:2013, Soil quality — Determination of dioxins and furans and dioxin-like polychlorinated biphenyls by gas chromatography with high-resolution mass selective detection (GC/HRMS)

ISO 10382:2002, Soil quality — Determination of organochlorine pesticides and polychlorinated biphenyls — Gas-chromatographic method with electron capture detection

ISO 18287:2006, Soil quality — Determination of polycyclic aromatic hydrocarbons (PAH) - Gas chromatographic method with mass spectrometric detection (GC-MS)

75. The performance of testing laboratories is variable. Countries should ensure that testing laboratories supporting monitoring of diffuse soil contamination fully meet international performance standards[17] by having auditable traceability of measurements, quality control systems incorporating standard reference materials, and participation in inter-laboratory comparability exercises.

4. Data analysis and management

76. Geo-statistics should be used to support the interpretation and presentation of data.[18] Data should be plotted and a visual inspection made to identify outliers with checks made that these are not artefacts of, for example, incorrect calculation. Before applying statistical analysis of data, compliance with the assumptions of the methods of analysis should be confirmed, e.g., if the data is not normally distributed it may require transformation. Geo-referenced sample data can be interpolated to create continuous surfaces of, e.g., contaminant concentration and change in contaminant concentration between sampling episodes, for example by kriging. Isopleths (locations in the landscape with the same predicted contaminant levels) can then be plotted to identify areas that are predicted to fall above or below target levels of contaminants.

5. Reporting

77. The value obtained by countries from monitoring diffuse soil contamination will be greatly enhanced if the data is accessible and freely available in a form that supports interoperability, i.e., in a format which is compatible with commonly employed information systems and that facilitates its extraction and analysis without pre-treatment. It is therefore recommended that data has attached metadata in standard format detailing spatial

[17] ISO/IEC 17025: 2005 general requirements for the competence of testing and calibration laboratories.

[18] Richard Webster and Margaret A. Oliver, *Geostatistics for Environmental Scientists*, 2nd ed. (London: Wiley, 2007).

coordinates and positional accuracy of samples, time of sampling, type, units and methods of measurement, etc., so that it can be combined with spatial data from other sources in a consistent manner without re-coding. This can be achieved by ensuring it is compliant with INSPIRE[19] guidelines for soil.[20]

C. Summary of key points

78. A strategy for managing diffuse soil contamination should focus on assessing its spatial distribution and trends to inform and aid the implementation of decisions about the control of sources of ongoing and new contamination.

79. There are many diffuse contaminants of soil and a selection for monitoring is required based on priorities for protection of the environment and public health.

80. An effective system for managing diffuse soil contamination requires:

(a) Information on the current levels and trends in soil contamination;

(b) Integration with and relevance to wider environmental policy objectives and contexts to assess where levels are excessive and sources of contamination require greater control.

81. An efficient monitoring system to support the management of diffuse soil contamination requires:

(a) Designation of a single institution for its development and maintenance;

(b) Quantitative measurement performance specifications for each contaminant included in monitoring;

(c) Modelling of the anticipated performance of design options using statistical methods to ensure that the monitoring system implemented is fit for purpose;

(d) Strict adherence to formal procedures and protocols for soil sampling and testing and data reporting;

(e) Maintenance of an archive of samples and data for future reference.

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[19] Directive 2007/2/EC of the European Parliament and of the Council of 14 March 2007 establishing an Infrastructure for Spatial Information in the European Community (INSPIRE).

[20] See http://inspire.jrc.ec.europa.eu/documents/Data_Specifications/INSPIRE_DataSpecification_SO_v3.0rc3.pdf.