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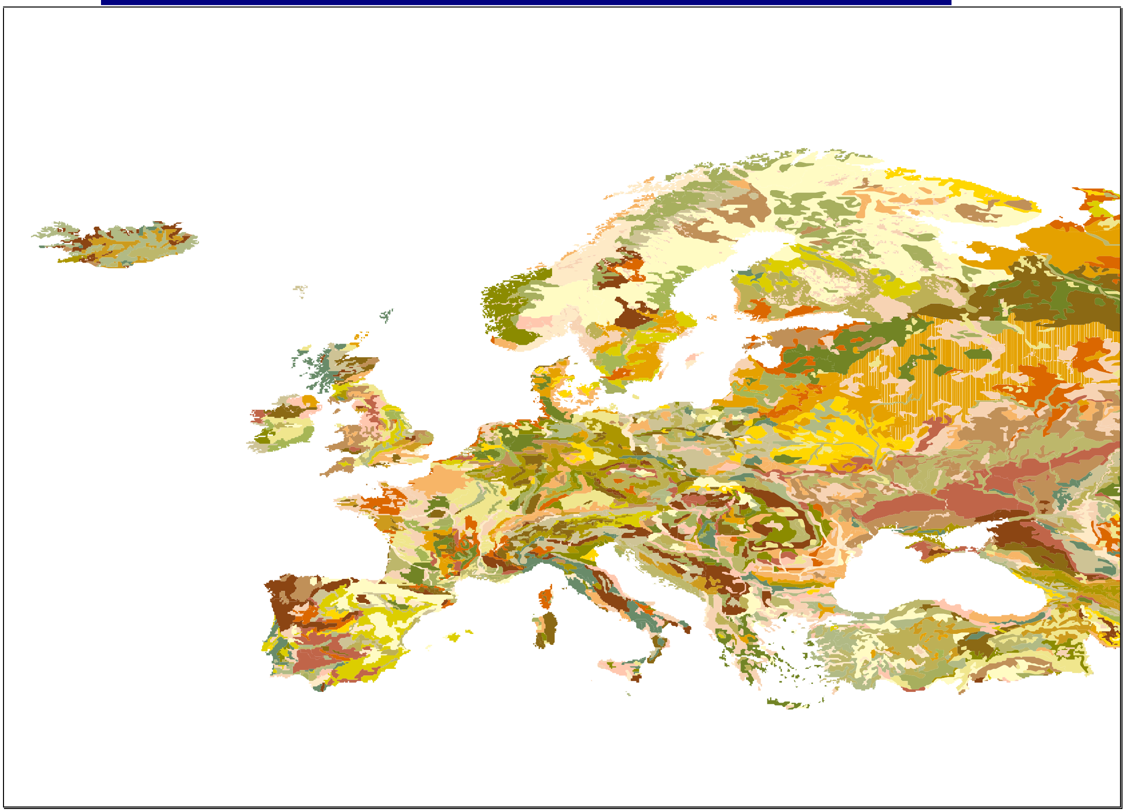
HEAVY METALS (TRACE ELEMENTS) AND ORGANIC MATTER CONTENT OF EUROPEAN SOILS

Feasibility Study

by

European Soil Bureau

Scientific Committee



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HEAVY METALS (TRACE ELEMENTS) AND ORGANIC MATTER CONTENT OF EUROPEAN SOILS

- A Feasibility Study -

Report by the

European Soil Bureau - Scientific Committée

to

MR. M. HAMELL – EU-DG XI D.I, Environment
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Contents

1. Abstract

The German Federal Environment Agency and DG XI of the European Union commissioned a feasibility study on trace element and organic matter contents of European soils. The reason for this was the imminent revision of the Sewage Sludge Directive 86/278/EEC. On the initiative of the Scientific Committee of the European Soil Bureau (ESB), an expert working group was formed from the 15 EU countries, which met for the first time in ISPRA, Italy from July 28 to 29, 1999. The members of the group decided to send out a questionnaire to the whole of Europe to elicit information on trace element and organic matter contents of soils and to use the results to make appropriate suggestions for further action.

The database of the individual countries proved to be very complex both qualitatively and quantitatively. Thus, the assessment across the whole of Europe proved considerably more difficult than anticipated.

For this reason a specific approach within a limited time span is proposed:

- a “short term action” over about one year, aiming to ascertain what the needs for data and standardisation in Europe are;
- a “long term action” over about three years, to fulfil the obvious need for standardisation and fill the gaps in data.

A European “Soil Monitoring System” should be set up using existing systems in the member countries of the European 15 (EU 15) and, if necessary, take further samples in regions that clearly need more data.

2. Introduction and Background

The protection of soils is and should be a principal objective of environmental policy. Soils are a finite, increasingly scarce and non-renewable resource with varying biological, chemical and physical properties. These should be protected and preserved in order to maintain the soils important ecological functions. Essential for environmental interaction, is the capacity of soils to act as a filter and buffer system against chemical degradation (acidification, heavy metals, pesticides and other organic pollutants, etc).

Besides any population growth, the upgrading of municipal wastewater treatment plants has led to increased sludge production. Sludge production and disposal are entering a period of dramatic change, driven mainly by European Commission (EC) legislation. The urban waste water treatment Directive will result in at least 50% more sludge being produced by the end of 2005 and, during the next decade, sludge disposal to all the established outlets could become increasingly difficult.

Sludge quantities are rising and disposal options decreasing.

Sewage sludge can be used beneficially on land as a soil conditioner and fertiliser, in a variety of ways. The utilisation of sewage sludge in agriculture is widely discussed. Application rates of sewage sludge are generally based on fertiliser requirements of crops. Landfill and incineration of sewage sludge deprives soils low in organic matter content of a potential source of organic material. On the one hand the content of nutrients like nitrogen, phosphorous and organic matter should be recycled by land application but, because of contamination with pollutants, acceptance is low. Among these pollutants, the presence of substantial amounts of heavy metals is well established.

Application of sewage sludge to agricultural land has the advantage of providing an economical disposal alternative, in addition to supplying plant needs for nutrients.

At the meeting on Soil and Soil Quality in Brussels (July, 2nd, 1998) the main objectives of Directive 86/278 with special regard to the protection of soils from heavy metals were defined. To support DG XI in the waste sector, in particular the upcoming revision of the Sewage Sludge Directive

(86/278/CEE), and the possibility of using biodegradable material through composting and anaerobic digestion, there is an urgent need to establish the heavy metal and organic matter status of European Soils.

Knowledge of the background content of heavy metals in soils is essential to a proper understanding of the current state of European soils in relation to waste disposal options. We take the term 'background content' to be that resulting largely from geogenic sources, as modified by soil forming processes, and largely without anthropogenic additions, i. e. that content against which the risks arising from further additions have to be judged. Knowledge of background levels of heavy metals for soils is scarce in most countries of the EU 15. Moreover, for a European-wide evaluation, the data compilation could be complicated by a different understanding of the term background levels and by variations in sampling and analytical methods throughout the EU 15.

The natural background level of heavy metals depends strongly on the origin of the soil and soil characteristics, since metals occur naturally in the earth's crust. The contamination of soils with heavy metals is caused by atmospheric deposition or by direct disposal on the soil. The direct disposal of heavy metals on soil includes industrial waste disposal, impurities in fertilisers and manure, sewage sludge and pesticides containing heavy metals. The use of sewage sludge is commonly found on cultivated land. Spatial data for heavy metal contamination are available for aerial deposition (e. g. moss monitoring programs in the countries of the European Union) but less is known about the spatial pattern of deposition through sewage sludge application or management.

The basis for much evaluation of soil and environment protection is built on element contents (so called background contents), most commonly of the so-called 'heavy metals', although these are also sometimes interpreted with other data such as soil pH, clay content and so on. Such element contents of soils can be used to delineate regions for which soil conservation plans can be drawn up for protection against harmful changes to the soils. In addition, element contents of potential soil pollutants can be used as reference or orientation values to reflect the "general risk posed by the soil". This is because element contents are dependent on soil conditions, which can be aggregated on a substrate, substances, land use and area-related basis. On an analogue basis, element contents, singly or in combination, can be used for calculating reference values, which are of great importance in regulating the use of residue materials.

Soil organic matter has a great influence on the chemical and physical properties of soil and makes up, together with the clay, most of the cation exchange capacity (CEC). The CEC is a key parameter describing the sorption and desorption of plant nutrients and contaminants by soil. The major input sources of organic matter to soils are manure, litterfall and crop residues, but the equilibrium content of soil organic matter is influenced by climate, land use and management, over time. Soils subject to continuous cultivation have a lower organic matter content than those under grassland. In the case of the soils in southern Europe, there is evidence that soil organic matter contents are decreasing by intensive agricultural land use under conditions which favour lower equilibrium values, e. g. higher average temperatures.

The Soil Profile Analytical database, that forms a component part of the European Soil Database, is an important repository for soil data but it is incomplete for the European area. There are also problems with spatially linking the profile data to the soil geographical soil map. Maps of the organic carbon content of European Soils were made, but the accuracy of these maps is not known, because they are based on a very small data set. Furthermore, the database does not contain any measured or estimated values for heavy metal contents of European Soils.

3. Objectives

Against this background, we propose a 'scoping' study. The objectives of the scoping study are to assess existing databases of trace elements and organic matter in soils with special regard to:

- Harmonisation of analytical methods, quality control and validation of existing data
  - sample description
  - sampling strategy
  - elements recorded in the data bases
  - further chemical and physical soil parameters recorded in the data bases
  - analytical methods
- Spatial representation of data
  - requirement of harmonisation of the results
  - comparability of presented evaluation/s
- Mapping of trace element and organic matter contents at the scale of the European Soil Map
- To define the approach for future activities at different time scales:
  - a short term action program
  - a long term action program

In order to make a start on this approach, we have undertaken a questionnaire-based survey of major soil data holders within Europe. The analysis of the response to this questionnaire is given below, as are our proposals for building on this foundation.

4. Results from the Questionnaire

The design of the questionnaire was in the responsibility of the Federal Institute for Geosciences and Natural Resources of Germany (BGR), who developed it in collaboration with the partners of the working group. Copies of the questionnaire were distributed by the Joint Research Centre, (JRC, Ispra), to the ESB Scientific Committee's "Contact Points" of each country of the EU 15.

4.1 Questionnaire Survey and Returns

The survey took into consideration the responses from 12 countries of the EU 15, albeit four of them could be used only with certain limitations. Italy only gave information for the province of Lombardy in detail, Belgium for the provinces Antwerpen/Westflanders and Eastflanders, Ireland only gave information for the south east of the country and in the case of Great Britain the information was restricted to England and Wales. Complete information were given by Austria, Denmark, Finland, France, Germany, Greece, The Netherlands and Spain.

With respect to Belgium and Greece, in all other countries the databases are in the responsibility of more then one institution. The database of Belgium is structured regionally, and the database contains the values of heavy metals and organic matter as well. For Finland, the information was given by the Agriculture Research Centre and the Geological Survey of Finland. The database of the Agriculture Research Centre contains both values for heavy metals and organic matter, but only for cultivated soils. The data collected by the Geological Survey of Finland are focused to heavy metals. France has two databases for heavy metals and a separate database only for organic matter contents in soils. For the Netherlands the data sets for heavy metals are held by the provincial authorities and for some projects unique to the DLO-research centre. Values of the organic matter contents of soils were gathered by the national Soil Information System. Ireland, Denmark, England/Wales and Spain use only one database for both, heavy metals and organic matter contents in soils, and in Germany, heavy metals and organic matter contents data are stored in a federal database at BGR and in similar structured databases of the 16 individual state Soil Surveys. The summary of the general results are given in table 1.

Table 1 : Questionnaire returns and detailed informations

	Response	HM+OM	Database	Data format		Owner of the database
Country				digital	Paper	
Austria	Yes	Yes	BORIS-Soil information system	X		Federal Environment Agency and Federal research centres.
Belgium	Yes	Yes; different Databases	1. Antwerpen, u. West-Flandern	X		Laboratory of Soil Science, Belgium
			2. East-Flandern			
Denmark	Yes	Yes	SAS-Database	X		National Environm. Research Institute
Finland	Yes	Yes; different Databases	1. HAPRO87	X		Agricultural Research Center of Finland
			2. ALKEMIA	X		Geological Survey of Finland
			3. ALKEMIA; Scale regional	X		Geological Survey of Finland
			4. Baltic Soil Survey	X		Geological Survey of Finland
			5. Forges; Geochemical Mapping	X		Geological Survey of Finland
France	Yes	Yes; different Databases	1. ASPITET	X		INRA; Orleans
			2. ADEME	X		Agence de l' Environment et de la Maitrise de l'Energie
			3. Carbon database	X		INRA; Orleans
Germany	Yes	Yes	1. FISBoBGR Soil profile database	X		BGR
			2. Sixteen Individual States Soil Information Systems	X		Individual Soil Survey Institutes
Greece	Yes	Only organic matter			X	National Agricultural Research Foundation
	Yes	Yes	Soil physical – chemical properties	X		National Agricultural Research Foundation
Ireland	Yes	Yes	Soils of the South East	X		TEAGASC
Italy	Yes	Yes	Soil information system of Lombardy	X		ERSAL
Luxembourg						
Netherlands	Yes	Yes; different databases	1. Databases of unique projects; RIVM (Nat. soil quality network)	X		Provincial authorities; DLO-Institute
			2. Soil information system	X		BIS: SC-DLO
Portugal						
Spain	Yes	Yes	IRNAS-SABm	X		CSIC
Sweden						
England/ Wales	Yes	Yes	National soil inventory	X		Carnfield University; Ministry of Agriculture, Fishers and Food

4.2 Assessment of the Existing Databases

4.2.1. General Characterisation of Soil Samples Including Sampling Strategy

In order to characterise soil samples, answers were sought as to the current land use, the soil parent material, the soil profile characteristics, the number of locations for soil sampling and the soil classification system used. Evaluation of this section of the questionnaire shows that:

Not all the data from each of the countries is kept in their respective databases. The data from the different databases has been adjusted according to the individual questions.

This point will be illustrated using Finland as an example. At present Finland has five databases with details of heavy metal contents and/or levels of organic matter. The Geological Survey of Finland's databases ALKEMIA 1 and ALKEMIA 2 (see Table 1) contain no information on land use, or a description of the soil profiles and, consequently, no information on the soil classification system used. In total, ALKEMIA 1 includes the results from 1056 samples, ALKEMIA 2 on the other hand, contains the results from 82,062 samples. The purpose of both databases is to provide information on the geochemistry of the country, the different number of samples providing information on the heavy metal contents of the subsurface layers at differing scales. A further database in the Geological Survey of Finland is being set up (Forges Geochemical Mapping), this "Baltic Soil Survey" databases having data from 132 samples (see Table 2). The "Agricultural Research Centre of Finland" 's database on the other hand contains information on the land use and the soil classification system used. The data are restricted to agricultural land use and were collated as part of a national monitoring programme.

In the databases of countries such as Austria, Denmark, Germany, Greece, Ireland, Italy, Spain and England/Wales, data on land use and soil parent material is complete and sometimes there is information on soil profile characteristics and the soil classification system. As far as the future application of these data to illustrate national results is concerned, Spain has only a small number of sample areas, and it is only possible on a regional basis in Italy, Belgium, Ireland and Great Britain.

In the majority of countries the samples were taken with the aid of a grid or by taking into account the soil parent material. In some countries, pedological interests were paramount. All countries georeferenced the samples, but accuracy fluctuates from 10 to up to 1,000 m. A resumé of the results is given in Table 2.

4.2.2. Specification of Soil Parameters

This section of the questionnaire was looking for answers about general chemical and physical soil parameters and the type of trace elements present. Furthermore, information was required on the country-wide coverage for all trace elements and the content of organic matter in the soils.

In the majority of cases, data was provided on the pH and soil texture. Information on cation exchange capacity, on sesquioxide content, carbonate and bulk density were, however, only given by some countries and, as explained in chapter 5.2.1, according to the questionnaire, kept in separate databases.

Samples were commonly taken from soil horizons, but data for all three soil horizons (A, B, C) were obtained in only a few cases. On the whole, A horizon samples were used. Samples taken from depth increments or as mixed samples were also used. Table 3 summarises the results.

As far as the trace elements are concerned, information about the following elements was asked for: As, Cd, Cr, Cu, Hg, Mo, Ni, Pb, Se and Zn. The results are summarised in Table 4. The individual countries, except Italy, keep data on Cr, Cu, Ni and Zn in each of the databases mentioned, but Finland and Greece have no data for Hg. Where Cd is concerned, all the countries, except for Italy, keep data, but Finland only has data in the "Baltic Soil Survey" database. Italy keeps data only on Pb. Information on Se and Mo contents are however only known by a few countries.

Table 2: General characterisation of the soil samples

Country		Current Land use	Locations	Parent Material	Soil Profile Characteristic	Soil Classification System	Criteria of Selecting Sites		
	Data sets						Sampling strategy	Sample unit [1.)]	Geo-ref.
Austria		X	4100; not all parameters	X	X	Soil taxonomy after Fink (1969)	Grid, excluding untypical located sites		X
Belgium	Data set 1	X	340	X	X	All	Grid; randomly chosen x/y origin	O	X
	Data set 2		As120, Cd422; Cr101; Hg108; Cu,Ni,Pb, Zn 422				Grid	O	X
Denmark		X	393 HM 40.000 OM	Maps		FAO 1990; WRB	Grid 7 x 7 km; random from uniform grid		
Finland	Data set 1	X	1300			National	Random, cultivated. Soils	A, MC	X
	Data set 2		1056	X			Parent Material; 1Sample/300 km^2	C	X
	Data set 3		82.062	X			Parent Material; 1Sample/4 km^2	C	X
	Data set 4	X	132	X			Grid 50 X50 km, arable Soils	D (0-25, 50-75 cm)	X
	Data set 5								
France	Data set 1	X	1291	X	X	National	Parent material.; soil series; pedol/geol.	A, B, C	X
	Data set 2	X	11414				Fields before spread. with sewage Slugde.	Ap	X
	Data set 3	X	7005			FAO 1990	Mix. of 4 different sources of data		
Germany	Data set 1	X	2417 profiles	X	X	National	Parent material, pedol. Interest	A; MC	X
Greece	Data set 1	X		X	X	Soil Taxonomy	Soil units	A; B, C	
	Data set 2	X		X	X	Soil Taxonomy		A	X
Ireland		X	295				Grid; Intersections and Centerpoints 2 samples/10 km^2	MC	X
Italy		X	103 HM 3000 OM	X	X	FAO 1990, Soil Taxonomy, WRB	Random for mapping, Located for Monitoring	A and A; B; C	X
Luxembourg									
Netherlands	Data set 1	X	3543	X	X	National	Land use/parent material	D ; 0-10 cm	X
	Data set 2	X		X	X	National	Land use/parent material	D ; 0-10 cm	X
Portugal									
Spain		X	100	X	X	FAO 1974; Soil Taxonomy	Pedological interset		X
Sweden									
England/Wales		X	10.000 As, Hg, Se; 5690 pH and OM; 3000 HM	X	X	National	Grid 5 km	MC	X

1.) Codes for Sample units: A, B, C for horizon; L for layer; D for Depth Increments; SC for Single Core; MC for Mixed Core; O for other

Table 3: General soil chemical und physical parameters

Country	Data Sets	pH	CEC	Exchangeable Cations	Sesquioxides	C-org.	Organic Matter	Carbonate	Soil texture	Bulk density	other	Sample unit [1.)]
		Soil Chemical Parameter							**Soil Physical Parameter**			**Sample**
Austria		X	X	X	X	X		X	X	X	X	
Belgium	Data set 1	X				X		X	X			O
	Data set 2	X				X			Estimated Clay			O
Denmark		X	X	X	X		X	X	X	X		
Finland	Data set 1	X				X			X	X		A, MC
	Data set 2											C
	Data set 3											C
	Data set 4	X				X						D (0-25, 50-75 cm)
	Data set 5											
France	Data set 1	X	X			X		X	X			A, B, C
	Data set 2	X	X			X	X	X; often	X; often			Ap
	Data set 3	X	X			X	X		X			A
Germany	Data set 1	X				X			X			A; MC
Greece	Data set 1	X	X	X			X	X	X	X		A; B; C
	Data set 2	X	X	X	X		X	X	X	X	X	A
Ireland		X				X	X					MC
Italy		X	X	X		X		X	X	X	X	A; B; C
Luxembourg												
Netherlands	Data set 1	X	X	X	X	X		X	X			D ; 0-10 cm
	Data set 2								X			
Portugal												
Spain		X	X	X		X		X	X	X	X	
Sweden												
England/ Wales		X				X			X			MC

1.) Codes for Sample units: A, B, C for horizon; L for layer; D for Depth Increments; SC for Single Core; MC for Mixed Core; O for other

Table 4: Analysed trace elements and country coverage for trace elements and organic carbon

Country		**Trace Elements**										**Country Coverage**		
	Data set	**As**	**Cd**	**Cr**	**Cu**	**Hg**	**Mo**	**Ni**	**Pb**	**Se**	**Zn**	**Published maps**	**Trace elements**	**Org. C**
Austria		X	X	X	X	X	X	X	X	X	X	Yes	100 %	100 %
Belgium	Data set 1		X	X	X			X	X		X			
	Data set 2	X	X	X	X	X		X	X		X			
Denmark		X	X	X	X	X		X	X		X		100 %	
Finland	Data set 1		X	X	X		X	X	X		X	only tests	100 %	100 %
	Data set 2	X		X	X		X	X	X		X	Yes	100 %	
	Data set 3			X	X			X			X	Yes	100 %	
	Data set 4		X	X	X		X	X	X		X	only tests	100 %	100 %
	Data set 5													
France	Data set 1	X	X	X	X			X	X		X			
	Data set 2		X	X	X	X		X	X	X	X			
	Data set 3											Yes		100 %
Germany		X; some	X	X	X	X		X	X		X	Yes	70 %	
Greece	Data set 1													
	Data set 2		X	X	X			X	X	X	X			
Ireland		X	X	X	X	X		X	X	X	X		23 %	23 %
Italy									X					
Luxembourg														
Netherlands	Data set 1	X	X	X	X	X		X	X		X	Yes		
	Data set 2													
Portugal														
Spain		X	X	X	X	X	X	X	X		X			
Sweden														
England/ Wales		X	X	X	X	X	X	X	X	X	X	Yes	100 %	100 %

Some countries, such as Austria, Finland, Germany, the Netherlands and England/Wales have produced maps showing the trace element and organic matter contents in the soils on the basis of their results in their various databases. Thus, between 23% (Ireland) and 100% (Austria, Finland, England/Wales) of the land area could be shown by maps using the data.

4.2.3. Evaluation of Analytical Methods

This section of the questionnaire was looking for answers on digestion procedures.

Not all the countries filled in this part of the questionnaire. According to the answers received, the trace elements, with two exceptions, were determined following acid digestion. The following acids or acid mixtures were used as digestion medium: aqua regia (A.R.), HF, $HF/HCLO_4$ or $HF/HNO_3/HCLO_4$ (total) and in one case $HNO_3/HCl/HClO_4$. Standardised methods were used by Austria, France, Germany and England/Wales. Austria, Denmark and France used national standardised methods, Germany and England/Wales, however, used the internationally valid ISO 11466. Quality control was guaranteed on the whole by using internal standards. Table 5a and b summarises the results of this section of the questionnaire.

Table 5a: Description of the analytical procedure for heavy metals

Country	Heavy metal				
	Data set	Digestion [1.)]	Standard (Iso etc.)	Number of labs	Quality control
Austria		$HNO_3/HCl/HClO_4$	ÖNORM L1085-89		
Belgium	Data set 1	A.R.		2	
	Data set 2	A.R		2	
Denmark		Nitric Acid	Danish Standard 259	1	Yes
Finland	Data set 1	HAAC-EDTA		1	Yes
	Data set 2	Total/A.R.		1	Yes
	Data set 3	A.R		1	Yes
	Data set 4	Amm.Ac and XRF		3	Yes
	Data set 5				
France	Data set 1	$HF/HClO_4$	AFNOR	1	Yes
	Data set 2	Total/A.R.	AFNOR, not Hg	>15	Yes
	Data set 3				
Germany		XRF/A.R./Total	ISO 11466	>4	Yes
Greece	Data set 1				
	Data set 2				
Ireland		Hydrofluoric Acid		2	Yes
Italy				3	Yes
Luxembourg					
Netherlands	Data set 1			<10	Yes
	Data set 2			<10	Yes
Portugal					
Spain					
Sweden					
England/ Wales		A.R.	ISO 11466	3	Yes

1.) Digestion: A.R. for aqua regia; HAAC-EDTA for Acid Ammonium Acetate-EDTA extraction; Amm.AC. for Ammonium Acetate Extraction; $HNO_3/HCl/HClO_4$ for a mixture of Nitric Acid/ Hydrochloric Acid/Perchloric Acid; Total e.g. for a mixture of Hydrofluoric Acid/ Nitric Acid/ Perchloric Acid and XRF for X-ray .Fluorescence Spectroscopy

Table 5b: Description of the analytical procedure for arsenic and selenium

Country	Arsenic and Selenium				
	Data set	Digestion [1.]	Standard (Iso etc.)	Number of labs	Quality control
Austria		$HNO_3/HCl/HClO_4$	ÖNORM L1085-89		Yes
Belgium	Data set 1				
	Data set 2	A.R		2	
Denmark		Nitric Acid	Danish Standard 259	1	Yes
Finland	Data set 1				
	Data set 2	Neutr Activ.An.;only As		1	Yes
	Data set 3				
	Data set 4				
	Data set 5				
France	Data set 1	H_2SO_4/HNO_3; only As		1	Yes
	Data set 2	Various meth.; only Se		>15	Yes
	Data set 3				
Germany					
Greece	Data set 1				
	Data set 2			1	
Ireland		$HNO_3/H_2SO_4/HClO_4$		2	Yes
Italy				3	Yes
Luxembourg					
Netherlands	Data set 1			<10	Yes
	Data set 2			<10	Yes
Portugal					
Spain					
Sweden					
England/ Wales		Nitric Acid	UK Analysts	3	Yes

1.) Digestion: $HNO_3/HCl/HClO_4$ for a mixture of Nitric Acid/ Hydrochloric Acid/Perchloric Acid; A.R. for Aqua Regia; H_2SO_4/HNO_3 for a mixture of Sulphuric Acid/ Nitric Acid; $HNO_3/H_2SO_4/HClO_4$ for a mixture of Nitric Acid/ Sulphuric Acid/ Perchloric Acid and Neutr Activ.An for Neutron Activation Analysis

5. Options for Further Investigations

The data for the individual countries is, where the analysis for trace elements on a European-wide scale is concerned, very complex both qualitatively and quantitatively. There is information on the level of trace elements from each of the countries, but on the whole it is specific to the country in question, and has been collated often according to particular aspects or issues. In some cases, data are only available for certain regions of the countries. At present, complete data on the levels of trace elements in soils can only be obtained for a few countries (e. g. Austria, England/Wales). European-wide spatial evaluation is not possible without further analyses and standardisation.

In contrast to trace elements, all countries have comprehensive information on the level of organic matter in soils. Organic carbon levels were mostly determined using an elemental analyser or by wet oxidation (for example, dichromate oxidation). The data are available in digital form with one exception (see Table 3). Information on the level of organic matter in soils in the whole of Europe is, in comparison with information on the levels of trace elements in soils, considerably easier to obtain and more accurate, because standardisation of procedures is far better and there are more data sets available.

The results of the questionnaire indicate clearly that there is a considerable amount of spatial data within the EU 15, with regard to heavy metals and soil organic matter contents. Although these data are in several different databases, we believe that they could be compared and harmonised to a first, but nonetheless acceptable, approximation by expert judgement exercised by a consortium of the data holders. We propose this as a **"Short Term Action"**, carried out over 12 months.

A follow-up, "**Long Term Action**" over roughly three years is also proposed. This would further improve our understanding of the inevitable disparities within the data, further standardise future data collection, both in terms of sampling, analysis and data management, and allow us to provide missing data through a minimum programme of sampling and analysis. Particular care has to be taken as to the long-term reliability of results in standardised analytical methods, because of the need to identify and quantify changes brought about by real environmental change, as opposed to those which might be due solely to improvements in analytical methodology. This kind of long-term quality control and harmonisation is best achieved by a European soil monitoring system, already present in various countries of the European Union. Such systems have already been standardised throughout Europe where particular issues are concerned (e. g. acidification of the soil). It seems to us both logical and practicable, as part of a long term action plan for the investigation of soil quality within Europe, to encourage the setting up of a European soil monitoring system. The starting point could easily be existing systems in the individual countries.

5.1 Short Term Action

The assessment of European data as part of the short term action can be accomplished by organising it in two ways:

- The individual countries assess the data with national experts according to previously established criteria, and with a final comparison of parameter levels with the other countries.
- All the basic data conforming to the minimum requirements, from the whole of Europe is collated and assessed on a European-wide basis.

Because of the time limit of approximately one year and the obvious complexity of the data available, it seems at present to be more sensible to have the data in the different countries assessed by national experts in the initial stages, according to the previously agreed criteria. Thereafter, one could continue with a European-wide assessment and standardisation, e. g. in terms of the class limits for particular substances. This will be the best way of reducing the time needed to standardise procedures. Apart from that, the extent to which the national institutes can provide their basic data on time to the working group is not immediately obvious. In the final analysis, expertise with regard to the individual databases remains with the institutions, which is the best way of avoiding misinterpretations.

5.1.1 Trace Elements in Topsoils

In order to access the trace element levels from the different countries in the European Union and then assess and illustrate their distribution (mapping), the following steps are proposed:

- Definition of the details to be regarded (minimum data sets)
- Standardisation of the data to be analysed where the following are concerned:
  - The point of references of the data (sample unit)
  - The digestion method used
- Standardisation of statistical methods used
- Spatial representativeness of point data
  - Map of soil parent material; determination and cartographic illustration of lithology/pedology parameters
  - Map of Main Land Uses; determination and cartographic illustration of land use areas
  - Determination of criteria to maintain a sufficient spatial representativeness in areas for different sampling strategies
- Assessment and illustration of data sets by the individual countries for sufficiently well-represented legend units/regions
- A comparison between the different countries and standardisation of the results, and an analysis of the deficiences and problems encountered.

These steps are described below:

Definition of the details to be regarded

A pre-requisite for an initial analysis of the trace element contents is a European agreement on the results to be shown. On the one hand the trace element contents and on the other hand the trace element background values in soils can be represented. As a basis for discussion, for definition of the term “Background Value of Trace Elements” the following is proposed:

The naturally occurring geogenic baseline contents and the ubiquitous anthropogenic additional input of substances into soil comprise the typical element contents in soils. Any particular, localised contamination should not be included for the purpose of calculating element contents of soils.

Standardisation of the data to be analysed

Standardisation of Data Regarding Sample Units

The sample units used in the analysis are shown in Table 2, Chapter 5. The sample was taken on an horizon basis in the majority of countries; some countries took samples as depth increments or as mixed samples. The mineral top soil should provide a reference for a sample unit because of its primary importance in the protection of soils. Pedogenetically top soils can include several A-horizons in the upper layers of some types of soils. Depending on the thickness and land use of the soils, top soil horizons are characterised by soil tillage (e. g. Ap-Horizons).

A combination of horizon and depth increments could be used as a way of bringing about standardisation, so that A-Horizons established as top soils could be characterised above a previously defined depth increment. The different depths increments must be defined according to differing land use.

Standardisation of Data regarding Digestion

Very different digestion methods were used to determine trace element levels (see Table 5). Only incomplete information is available for this section of the questionnaire, but from the replies received it can be deduced that national methodological standards were used as well as the internationally recognised ISO standards. This means that there is a broad spectrum of acid digestion or extraction methods for the determination of trace element levels (see Table 5a and b). A standardisation of the data to be analysed could be brought about by combining similar acid digestion/extraction methods. This means that content levels shown have to be much broader, but would provide quite reliable results on a European scale. Generally trace element levels were obtained by using aqua regia, so that these results could be used as a reference. The results of other acid digestion/extraction procedures (e. g. total digestion with HF-$HClO_4$-HNO_3) would have to be adjusted, and could be done so by reference to 'recovery values' from Certified Reference Materials, data for which are held by most laboratories. Statistical estimation methods are partially already available.

At present the levels of Chromium (Cr), Copper (Cu), Nickel (Ni) and Zinc (Zn) are available in the databases mentioned by the countries, meaning that after standardising the data to be analysed a European-wide assessment of these elements is possible. More data is needed for arsenic (As), cadmium (Cd), mercury (Hg), molybdenum (Mo), lead (Pb) and selenium (Se) (see Table 4).

All laboratories taking part guarantee a minimum of quality assurance using internal standards according to the current level of technology.

Standardisation regarding the statistical methods used

Agreement on the statistical methods to be used and the eventually sizes to be aimed for (e.g. range, percentile) has to be reached before the individual countries assess their data.

Spatial Representativeness of Point Data

Map of the Soil parent material

Soil parent material and land use are major factors in the distribution of trace elements in soils. For this reason a hierarchy of references in deducing trace element levels must be created. Due to the dominating lithogenic/geogenic origin of trace elements in unpolluted soils a differentiation according to soil parent material seems the most important. It is still to be decided which soil parent material should be used for European assessment. A cartographic description of the soil parent material in European soils is realistic on the basis of the Soil Geographical Database of Europe. Table 2 shows that all countries have data on the soil parent material.

Map on Main Land Use

Apart from “soil parent material”, land use is an important reference for differentiating trace element levels in top soils. A relevant map on main land uses (agricultural, grassland, forestry) can be made available from CORINE LANDCOVER data. The extent to which other land uses in Europe have to be shown, has still to be decided upon.

Maintaining sufficient spatial representativeness

The requirements of spatial representativeness of point data should be combined with a statistically restricted amount of samples for each section and

- include a reference to the soil parent material and
- provide a land use linkage.

As samples are georeferenced as a rule, combining them with corresponding information on areas is possible, but it has to be respected that information must not meet the spatial information, given by an overview map of the soil parent material. Moreover criteria for the spatial representativeness have to be agreed upon and laid down according to the individual sampling strategy.

National Assessment and Illustration of Data Sets

Based on the minimum data sets agreed upon, the evaluation process used and references, initially an assessment and illustration of the data available by national experts in the individual countries is proposed.

Comparison and Standardisation of the Results, Analysis of Problems

Data on the maps/regions regarded as being sufficient at a national scale must be compared with the rest of Europe. As a result of this, a 'Level 0' map of trace elements in topsoils in Europe, differentiating between soil parent material and land use is expected. Such a map would undoubtedly show areas with no data, insufficient data, or where interpoloation was, in the opinion of experts, being stretched beyong reasonable bounds discussions on these problems will help develop the standardisation process, for which there is an obvious need, in the light of further work.

5.1.2 Organic Matter in Topsoils

Where the **levels of organic matter are** concerned, a need for standardisation is much less great. Results from the elementary analysis and the wet oxidation can be directly compared up to a soil organic matter level of about 12 %. A first estimated data set corresponding to Soil Typological Units can be taken directly from the Soil Geographical Database of Europe as a spatial reference. The relevant reference to land use for humus levels can also be made from the CORINE LANDCOVER Data. Analogous to trace element contents, the spatial representativeness gives similar limits of interpretation.

The following steps are proposed as part of the short range action:

- Definition of the details to be regarded (minimum data sets)
- Standardisation of statistical methods
- Spatial representativeness of point data
  - Map of the soil typological units; determination and cartographic illustration
  - Map of the main land uses; determination and cartographic illustration of land use area
  - Determination of criteria to maintain sufficient spatial representation for different sampling strategies.
- Assessment and illustration of data sets by the individual countries

These steps are described below:

Definition of the details to be regarded

The organic matter in the soil can be described quantitatively by the organic level of carbon. Both are closely related and can be correlated with each other using simple formulae.

Standardisation of the statistical methods used
Analogous to the evaluation of the trace element levels an agreement of the statistical methods to be used has to be reached before the individual countries assess their data.

Spatial representativeness of point data
Requirements for checking the spatial representativeness of point data should be combined with a statistically verifiable spot check for each section and

- show a reference to the Soil Typographical Units and
- permit a land use linkage.

As sampling areas are usually georeferenced, a connection with corresponding spatial data is straight forward.

Map of the Soil Typographical Units and Main Land Use
The organic matter levels of soils are mainly dependent on the soil units and their individual land uses. In addition to the method of verifying the spatial representativeness of trace elements in soils a hierarchy in the reference bases in Soil Typological Units and land use is to be created.

A map of land uses can be made on the basis of CORINE LANDCOVER data, a map of the Soil Typographic Units could be made using the data from the Soil Geographical Databases of Europe. In both cases agreement must be reached on the contents of the soil typological units and the land use units to be shown.

Maintenance of sufficient spatial representation
As well as comparing levels of trace elements, a discussion of the criteria towards maintaining representation of areas is necessary for different sampling strategies where data on organic matter in soils is concerned.

Assessment and Illustration of Data Sets
Based on agreed minimum data sets, analysis methods and references, an assessment and illustration of the data available by national experts in the individual countries is proposed. Data on the maps/regions regarded as being sufficient at a national scale must be compared with the rest of Europe.

5.2 Long Term Action

After the approximately one year "short term action", a "**long term action"** limited initially to about three years should follow, with the aim of clarifying the deficits manifested in the method of data standardisation and filling in the missing data throughout Europe by taking additional samples.

The need shown by the questionnaire for standardisation even at the meta-data level, is probably true for other aspects of soil protection (e.g. organic trace elements, filterering and buffering capacity). For this reason it is important that research on the problems of levels of organic matter and trace elements in topsoils should be undertaken as part of a European Soil Monitoring Network. This would be the most effective way of ensuring that attempts to standardise soil protection in Europe are sustained. This is the only way of guaranteeing that possible changes in the parameter levels in soil in the future can be identified by comparative research. The creation of the European Soil Monitoring Network means that the effectiveness of soil protection measures can be verified at a European level. In order to control costs and the amount of work involved, the network should, as far as possible, work together with the other monitoring networks in EU countries. The European Topic Centre on Soil, for example, has already provided ideas that could be applied on the establishment of a European Soil Monitoring Network using existing national and regional monitoring networks.

For this reason, and as part of the long term action, the crucial issues of organic matter and trace element levels in topsoils must at the moment be given more priority. This is particularly true for the following aspects:

- Selection of representative sampling sites
- Sampling strategy
- Establishment of minimum data sets
- Simplification of analytical procedures.

In other words, every additional sample taking in regions with obvious data gaps should be utilised to encourage systematically the establishment of a European Monitoring Network and potentially to deal with more issues than at present.

As well as simplifying analytical procedures, a working group such as the ICP-Forest Program should be active as part of the long term action, specifically to ensure quality control of analyses. One way of achieving this would be by carrying out ring tests systematically between the laboratories involved, under the auspices of the Joint Research Centre (ISPRA).

EUSIS has been set up using the data bases "Soil Geographical Databases of Europe" (SGDE), "Soil Profile Analytical Database of Europe" (SPADE) and "Hydraulic Properties of European Soils" (HYPRES). The SPADE database has a key role to play where the current issues of trace element and organic matter levels in European soils are concerned.

Data collection, data storage and data interpretation in the frame of this study and applying the European Soil Information System (EUSIS), should be processed under the European Soil Bureau, and handled by a data holding capacity which must be linked closely to the ESB. A soil monitoring program, initially starting with the spatial distribution of trace elements levels and organic matter contents could fulfil the needs of sustainable land use and soil protection European-wide.

6. Conclusions

- Sewage sludge can be used beneficially on land as a soil conditioner and fertiliser, but, because of contamination with pollutants, the application of sewage sludge requires knowledge of trace element contents in soils.

- Under intensive agricultural land use conditions, there is evidence that soil organic matter contents are ongoing decreasing, mainly in soils of southern Europe.

- Knowledge of trace element and organic matter contents in soils is essential to a proper understanding of the current state of European soils in relation to waste disposal options.

- A European-wide assessment of trace element and organic matter contents in particular areas is not possible without more in-depth analyses and standardisation.

- A specific approach within a limited time span is proposed:
  - a "short term action" over about one year, aiming to ascertain what the needs for data and standardisation in Europe are;
  - a "long term action" over about three years, to fulfil the obvious need for standardisation and fill the gaps in data.

- A European "Soil Monitoring System" should be set up using existing systems in the member countries of the European 15 and, if necessary, take further samples in regions that clearly need more data.