MAPPING OF SOIL AND TERRAIN VULNERABILITY TO SPECIFIED CHEMICAL COMPOUNDS IN EUROPE AT A SCALE OF 1:5 M

Proceedings of an International Workshop
held at
Wageningen, the Netherlands (20-23 March 1991)

Report of working group discussions and recommendations

N.H. Batjes (Editor)
May 1991

SOVEUR

Workshop organised in the framework of the
CHEMICAL TIME BOMBS PROJECT
of
VROM - IIASA - MA
by the
INTERNATIONAL SOIL REFERENCE AND INFORMATION CENTRE

CTB

ISRIC

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Sponsor:

Netherlands Ministry of Housing, Physical Planning and Environment (VROM)
and
International Institute for Applied Systems Analysis (IIASA)
through the
Chemical Time Bombs Project (CTB)
of the
Foundation for Ecodevelopment "Mondiaal Alternatief" (MA)

INTERNATIONAL SOIL REFERENCE AND INFORMATION CENTRE

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1. INTRODUCTION

1.1 Background

Over the years, chemicals used in urban centres, agriculture, forestry, industry and construction have gradually accumulated in the environment. These anthropogenic contaminants are increasingly interfering with the "natural" functions of the soil environment. Past and present influxes of pollutants are irreversibly damaging the soil's function as a physical and chemical substratum for biomass production, modifying/reducing its initial buffering, filtering and transforming function, and are also altering the genetic diversity of plants and animals. Ecologically sustainable use of natural resources, including soils, is the biggest challenge society is facing at the eve of the 21st century. Mankind has no option but to find a timely and lasting solution to the problem of environmental degradation. This necessity has been recognized by scientists (e.g. Arnold *et al.*, 1990; Barth et L'Hermite, 1987; Benckiser *et al.*, 1991; Bridges, 1987; De Vries and Kros, 1991; Glazovskaya, 1991; Klimo and Saly, 1985; Kovda, 1990; Oldeman *et al.*, 1990; SCOPE, 1984; Sverdrup *et al.*, 1991) and policy makers (e.g. Council of Europe, 1990a and 1990b; UNEP, 1982; UNICEF/UNEP, 1990) who are increasingly paying attention to the problems of soil pollution.

These proceedings contain a report of an international workshop which was hosted and organized by the International Soil Reference and Information Centre (ISRIC) from 20-23 March 1991 in Wageningen, the Netherlands. The objective of this meeting was to consider the feasibility and desirability of initiating a project on the mapping of soil and terrain vulnerability to specified categories of chemical compounds in Europe at an average scale of 1:5 M (SOVEUR). The SOVEUR workshop was part of a series of seminars organized by the Foundation for Ecodevelopment "Mondiaal Alternatief" within the operational framework of the Chemical Time Bombs (CTB) project. The CTB project was launched in January 1990 as a joint venture between the Netherlands Ministry of Housing, Physical Planning and Environment (VROM) and the International Institute for Applied Systems Analysis (IIASA) at Laxenburg, Austria, in appreciation of the necessity to produce and utilize chemicals which do not disrupt the ecological functions of soils.

Stigliani (1991) defined a chemical time bomb as *"a concept that refers to a chain of events resulting in the delayed and sudden occurrence of harmful effects due to the mobilization of chemicals stored in soils and sediments in response to slow alterations of the environment"*. The factors and processes which determine the occurrence of chemical time bombs are discussed by Stigliani (1988 and 1991). The findings and recommendations of earlier CTB-workshops are included in reports of "Mondiaal Alternatief" (Smidt, 1990; Csikós, 1991).

1.2 The SOVEUR workshop

Thirty nine representatives from 17 European countries attended the SOVEUR workshop (see Appendix III). Central and eastern European countries were particularly well represented. Delegates of the European Environmental Research Organization (EERO), the Food and Agricultural Organisation (FAO) and the International Society of Soil Science (ISSS) also participated in the workshop. A number of invited scientists from France, Germany, Portugal and the Commission of the European Communities could not attend the workshop, but they expressed their wish to be kept informed about the progress of the SOVEUR programme.

4) Important natural and man-made factors/processes or so-called "triggers" which can modify the soil system's vulnerability with respect to the above chemical compounds are:
   - acidification
   - eutrophication
   - salinization
   - erosion
   - climate change
   - land use change
   - man-induced hydrological changes

5) There is a need to differentiate between:
   a) "Strong, delayed responses" which may be observed in soils that accumulate large amounts of mobile or mobilizable chemical compounds within the soil-plant-fauna system (e.g. mobilizable upon erosion or acidification). Repercussions thereof occur mainly as "on-site" effects, i.e. in proximity off the affected site.
   b) "Weak, rapid responses" which may be observed in soil systems from which chemical compounds are easily lost by leaching, either laterally (run-off) or vertically (to substratum/groundwater). These have been referred to as "whimpers".

   The first model (a) stresses the capacity of the soil reservoir and a trigger system. Application of a trigger, such as a change in land use, may cause sudden catastrophic releases of pollutants into the environment, corresponding with chemical time bombs. The severity of the environmental impact will vary with the degree of vulnerability of the soil system to the chemical contaminant and with the type of trigger. The second model (b) concerns soil systems in which contaminants accumulate, resulting in the gradual leakage of these compounds from the soil system in quantities similar to their actual/past rate of deposition. This is also a time delayed response but there is no trigger effect in this instance. Such occurrences, although troublesome, cannot be described as catastrophic episodes of pollution. Several participants therefore stated that we should not speak of a chemical time bomb in this instance but rather of "more or less" polluted areas. Other contributors objected to this point of view by observing that the capacity of the soil reservoir to retain and release specific chemicals may still be liable to change with time in response to slow alterations of the environment. It was noted also that soil systems with different capacities for storing a particular chemical compound may nevertheless display similar rates of leakage.

6) Discussions took place on changes in the capacity of the soil reservoir to hold contaminants subsequent to changes in the ambient conditions (e.g. pH-status, redox potential and climatic change). From the preceding discussions it followed that we should simultaneously consider the *capacity* of the soil system to retain/release specified chemicals, the actual *degree of loading* of the system with these chemicals, the type of *triggers* which act upon the soil system, and the *sensitivity* of the soil to the respective triggers. The dynamics of these time-dependent responses can be assessed through modelling.

7) Discussions took place on the need to combine information on soil vulnerability with data on loading (with reference to specified contaminants) to determine potential risk areas. It is important to consider the spatial variability in loading with specified chemical compounds.

6) A discussion arose as to whether the key parameters should be stored as "class-values" or as actual values. Critical limits for defining class-boundaries vary widely at the international level (Vogel, 1986). Preference was expressed for storage of the actual data since these can easily be converted to appropriate classes using simple threshold models when the need arises (enhanced flexibility in using the datasets). The actual data should be used for quantitative modelling. If modellers choose to apply theoretical distribution functions to class values (e.g. Monte-Carlo simulations) this should be clearly indicated!

Table 1. Key parameters relevant in determining the vulnerability of soils to specified chemical compounds following alterations of the environment (e.g. change in land use or global acidification).

Parameters	Chemical compounds		
	A	B	C
PARENT MATERIAL			
geochemical background	-	-	
primary CaCO3 content	-		-
content of weatherable silicates	-	-	
texture	-	-	-
SOIL			
depth	-	-	-
thickness of horizons (depth of sampling)	-	-	-
texture	-	-	-
clay mineralogy	-	-	-
Fe- and Al-hydroxides and oxides	-		-
specific surface area	-	-	-
pH (depth of decalcification)	-		-
organic matter content	-	-	-
type of organic matter	-	-	-
internal soil drainage (redox conditions)	-	-	-
percolation rate	-	-	-
GROUND WATER / SURFACE WATER			
depth of groundwater table	-	-	-
fluctuations in the above	-	-	-
direction of water flow	-	-	-
rate of water flow	-	-	-
chemical composition of seepage water	-	-	-
chemical composition of surface water	-	-	-

Note: A, B and C are contaminants to be specified (e.g. heavy metals, pesticides); -: means that this key parameter should be considered when assessing the vulnerability of the soil to this contaminant (Adapted after: Klijn, 1991).

2.3 Selection of chemical contaminants

1) Discussions arose about which chemical compounds should be considered in the SOVEUR programme taking into account the wide diversity of chemical contaminants, the present status of knowledge pertaining to the environmental behaviour of these compounds, and the time frame proposed for completion of the exercise. It was decided that we should first focus on a limited number of contaminants showing similar environmental behaviour (persistence, toxicity and mobility).

2) In case of heavy metals, for instance, such a grouping could be based on the response of certain elements to varying pH conditions (DVWK, 1988; Blum, 1990). Often, only the effects of changes in value of single parameters on elemental mobility are considered. Soils, however, are complex systems so that other possible interactions should also be considered. The latter relationships can be studied using transfer functions. The sorption of heavy metals in soil systems, for instance, is often correlated with pH, texture, mineralogy, organic matter content and type (mor or mull). The relevant relationships should be derived from desk studies.

3) A wide range of pesticides is applied to various crops and the kinds of pesticides used vary from country to country. These organic chemicals should be grouped according to their affinity for sorption, degradability under aerobic and anaerobic conditions, and transport properties in relation to the pH, humus and clay contents of soil systems. Blüme and Brümmer (1987) developed a method to forecast the environmental risk of pesticide contamination occurring at a specified site as well as a procedure to derive this type of information by making use of maps of soil and meteorological conditions. The general consensus was that two "categories" of organic pollutants should be considered in the SOVEUR mapping exercise; these compounds are to be identified by expert-panels. It was noted, however, that standard analytical procedures for determining organic chemicals in soils are not yet fully developed (see Kördel and Wahle, 1990; Benckiser *et al.*, 1991).

2.4 Miscellaneous discussion points

1) There is a need for agreement on threshold concentrations of selected chemical contaminants in soils, both at the national and European level.

2) The use of the FAO/Unesco (1974-1981) map as the basis for the SOVEUR programme was questioned, as it is known that some of the information on it may be out of date. There was no general consensus on the matter; participants from some countries did not foresee any problems, whereas others did. National members will compile modifications for the 1:5 M FAO/Unesco Soil Map of Europe, including such revisions necessary to incorporate the information held in national soil survey databases.

3) A polygon based, digital version of the FAO/Unesco (1974-1981) map can be obtained from UNEP-GRID in Geneva (public domain), while a grid version is available at IIASA, Laxenburg. In SOVEUR work will be with polygons so as to use physiographic/terrain units recognizable by users. The corresponding polygons can easily be rasterized if the need arises. The key attributes for the accompanying point data should be updated using the expertise available at the national level.

4) Which mapping scale is considered useful for planners? The aim of the SOVEUR programme is to produce a 1:5 M map which can be used for identification of areas having similar vulnerability to specific categories of pollutants. This map can serve as a basis for decision making at the European level and it permits the identification of potential problem areas which should be considered in

most vulnerable soils. This will encompass a qualitative assessment of the capability of the soil reservoir to release accumulated pollutants following changes in land use, global acidification or climatic change. The considered chemicals are potential toxicants, that are mobilizable and persistent, and also a source of public concern because of past, present and future loading. The assumptions used will be compatible with the resolution of the mapping exercise.

Project-1b: As for project-1a plus identification of major sources of point and diffuse soil pollution, and mapping (sampling programmes) of the accumulated load and rate of loading of the soil system so as to assess the risk of occurrence of CTBs. This approach can only be successful at the European level if standardized sampling, analysis and methodological procedures are introduced. The relevant principles and procedures should be documented in a manual. This approach should be developed and refined in sample areas at scales larger than 1:1 M (e.g. Danube project, Finno-Scandian area, Central Europe). Maps of actual loading and quantified assessments of capacities should also be prepared for these sample areas. Organizations to carry out these activities should be identified, and coordination of their activities at the European level would be desirable.

Project-1c: Study of delayed dose-response relationships using dynamic simulation models developed for specific chemicals so as to predict the risk, severity and time of occurrence of chemical time bombs in a given location.

Project-2: Mapping and studying of 'hot spots' which are geographically defined, highly polluted areas corresponding with "exploded" chemical time bombs (e.g. Danube Catchment Area project).

2) Three alternative scenarios for the implementation phase of SOVEUR have been identified, viz.:
   a) A project with a duration of one year for which financing will be sought with support of the CTB-project. This project conforms with "project-1a" as formulated above.
   b) A programme with a proposed duration of at least 2 years, which will encompass stages 1a, 1b and 1c for which funding will be sought from a multitude of agencies.
   c) A project with a proposed total duration of at least three years which will include the activities described for projects 1a, 1b and 1c as well as for project-2. Funding will be sought from international agencies. The International Society of Soil Science expressed its willingness to endorse this proposal.

3) Discussions took place on the size, recommended spatial resolution and geographical siting of the sample areas in association with the activities of the SOTER project of ISSS as planned for Central Europe and the Balkan area. The mapping scale recommended for the initial pilot areas is 1:1M. Each pilot area will encompass several countries so as to promote international cooperation with respect to the problems of soil pollution. Participants from the various regions of Europe expressed a clear interest in having sample areas of higher cartographic resolution (scale > 1:1M). These sample areas should include a number of chemical "hot spots" (see project-2). A GIS-based approach will facilitate this "zooming-in" exercise which will require a multiplicity of different features on overlays. Demonstration of the usefulness of the above methodology can serve as a basis for seeking additional funding for subsequent studies in other regions of Europe (e.g. Central Europe, Balkan area, Finno-Scandian region, Mediterranean).

4) The general time frame available for completion of the soil vulnerability mapping exercise within the context of the Chemical Time Bombs project was discussed. The aim then would be that the final product - 1:5M soil vulnerability map for Europe plus accompanying booklet - will be completed before June 1992, i.e. two months before the workshop which will conclude the CTB-project (2 - 6

11) The results of the SOVEUR workshop will be presented in the CTB-workshop for the Nordic catchment area (Uppsala, 14 and 15 September 1991) prior to the Second International Symposium on Environmental Geochemistry.

4. CONCLUDING REMARKS

A cooperative and fruitful discussion of the issues took place throughout the workshop when the group tackled the problems involved, the definitions and procedures. A wide range of participants expressed their thanks to VROM and the Chemical Time Bomb project for funding the workshop, and to ISRIC for organizing and hosting it. The observer of FAO stressed the need for soil vulnerability mapping at global level and willingness on behalf of FAO to assist with national requests pertaining to relevant materials. The director of ISRIC expressed the hope that FAO, as well as other international organizations such as the EC and UNEP, would show an active interest for the SOVEUR activities; ISSS could be instrumental in obtaining this recognition.

Speaking on behalf of VROM and the foundation for Ecodevelopment, Mrs Smidt indicated that representatives from many countries had agreed on the problem of CTBs, recognizing the need for cooperation with respect to addressing this important and complex matter at the European level. The way of thinking about soil vulnerability mapping as developed during the workshop should already be applied by the participants while concerted efforts are made to obtain funds for the implementation phase. Dr E.M. Bridges, chairman of the day, closed the workshop.

ACKNOWLEDGEMENTS

Special thanks are expressed to Dr. W.E.H. Blum, Dr. E.M. Bridges, Dr. G. Várallyay and Dr. W.G. Sombroek, the chairmen of the workshop. The support received from Mike Bridges is particularly acknowledged. I appreciated very much the assistance of colleagues from ISRIC during the organization of the SOVEUR workshop.

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APPENDICES

Appendix I Programme of workshop

Tuesday 19 March: Arrival of participants in Wageningen; check-in at IAC.

Wednesday 20 March:
(Chairman: W.G. Sombroek; rapporteur: N.H. Batjes)

8:30 - 9:00 Registration of participants at ISRIC (see Appendix IV).
9:00 - 9:15 Welcome address by Dr W.G. Sombroek, Director of ISRIC.
9:15 - 10:15 Scope of the SOVEUR project and main issues involved. Introductory presentations by:
9:15-9:35: Dr G.P. Hekstra on behalf of VROM.
9:35-9:55: Drs G.R.B. Smidt, coordinator of the CTB Project.
9:55-10:15: Dr J.V. Lake, European Environmental Research Organization (EERO).

10:15 - 10:30 Coffee break

10:30 - 12:30 Presentation of SOVEUR papers: problem identification, data availability and procedures used at European level; country reports (see Appendix III).
10:30-10:50: Presentation by W. Salomons, the Netherlands
10:50-11:10: Presentation by F. Klijn, the Netherlands
11:10-11:30: Presentation by J. Kuylienstierna, United Kingdom
11:30-11:50: Presentation by W. Sombroek, the Netherlands
11:50-12:10: Presentation by W. Wenzel, Austria
12:10-12:30: Presentation by E. Abts, Belgium

12:30 - 14:00 Lunch break

14:00 - 15:30 Country reports (continued).
14:00-14:20: Presentation by M. Penkov, Bulgaria
14:20-14:40: Presentation by B. Jurani, Czechoslovakia
14:40-15:00: Presentation by R. Schmidt, Germany
15:00-15:20: Presentation by G. Varallyay, Hungary

15:30 - 15:45 Coffee/tea break

15:45 - 18:00 Country reports (continued)
15:45-16:05: Presentation by C. Ciavatta, Italy
16:05-16:25: Presentation by J. Glinski, Poland
16:25-16:45: Presentation by M. Bessa, Portugal (cancelled)
16:45-17:05: Presentation by C. Rauta, Romania
17:05-17:25: Presentation by D. de la Rosa, Spain
17:25-17:45: Presentation by A. Desaules, Switzerland

Appendix II Titles of presentations

Introductory presentations

G. Smidt:	Introduction and framework of the Chemical Time Bombs project
J. Lake:	Soil vulnerability and chemical pollution: The nitrogen cycle in U.K. agriculture as an example

Soil vulnerability mapping; general considerations[3]

W. Salomons:	Processes in the soil affecting mobility of contaminants; what information do I need from a soil vulnerability map?
F. Klijn:	Environmental susceptibility to chemicals: from processes to patterns with special reference to mapping characteristics and spatial scales.
J. Kuylienstierna:	The sensitivity of soils and ecosystems to acidic depositions.
W. Sombroek:	Available maps and materials at European scale on soil, terrain, hydrology, climate and land use practices.

Data availability and methodological approaches to soil vulnerability mapping as used in the various countries of Europe.

W. Wenzel:	Monitoring of chemical impacts on soils in Austria.
E. Abts:	Status of research on soil vulnerability to chemical compounds and related mapping exercises in Belgium.
M. Penkov:	Basic characteristics for mapping (Bulgarian) soils vulnerable to chemical contamination.
B. Jurani:	Soil vulnerability to acidification in Slovakia: Principles of evaluation.
R. Schmidt:	Soil vulnerability assessment and chemical soil degradation in Eastern Germany.
G. Varallyay:	Soil vulnerability mapping in Hungary.
C. Ciavatta:	An Italian approach to the determination of vulnerable areas.
J. Glinski:	Chemical pollution of Polish soils.
C. Rauta:	Some aspects concerning the approach for mapping of soil and terrain vulnerability to specified groups of chemical compounds in Romenia.
D. de la Rosa:	Mediterranean soils degradation and environmental contamination. Special reference to Andalusian soil mapping and evaluation activities.

[3] Only the name of the person who gave the actual presentation is listed here for brevity's sake.

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