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Analysis and estimation model of contaminated soils

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Abstract: **The paperwork presents and analyzes the main stages of the estimating process of contaminated soil risk, namely: to develop a land conceptual model (LCM); to compare the LCM with the soil working scenario (SWS), to define data collecting necessity for identifying the areas surpassing the SWSs, to sample and to analyze the soils on site, to calculate the SWSs specific to the site, to compare the contaminating element concentrations of soils with computed SWSs, to make decisions regarding the need of later surveys. In managing the contaminated soils, a full strategy should be applied taking into account: all the functions the soil could have, its variability and complexity, degrading processes as well as the social-economical aspects intervening in setting the soil quality.**

Keywords: soil, model, dispersion, contamination

1. INTRODUCTION

The human society development determined the emergence of some effects that could lead to radical changes in soil quality. That is why the early knowing of such issues, their proportion and gravity estimation, the qualitative and quantitative soil degradation estimation are very important features for a sustainable development.

Development of a soil quality monitoring system currently represents a necessity and should include the surveillance, estimation, prognosis, warning and operating intervention regarding the current state of soil quality and its evaluation trend. The maintenance, evaluation and interpretation of soil quality should be considered as complex processes in which the soil resources are estimated based on soil functions and on their changes as response to the natural specificity or to the tension induced by actual management.

2. GENERAL CONCEPTS IN MONITORING SOIL QUALITY

While estimating soil quality the physical, chemical and biological process and properties should be considered and the following steps should be passed over:

a) Defining the soil functions
b) Setting the processes within the soil associated to these functions
c) Setting the properties and indicators with high sensitivity in sensing the changes of soil functions and processes

In monitoring the changes and determining the tendencies regarding the improving and degrading of soil quality, it is necessary the selection of its specific indicators and value thresholds in order to preserve the soil functions in a normality state [4].

Figure 1 shows the soil contamination spectrum and the conceptual response form in managing contaminated soils. In order to set up the quality level of soils, their contaminating levels should be considered and, depending on their contamination degree, the operative intervention should be applied.

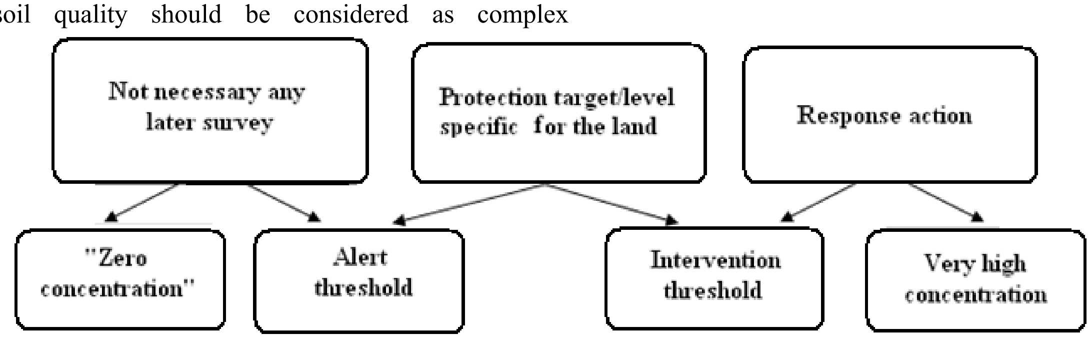

Figure 1. The soil contamination spectrum and conceptual response form in managing contaminated soils.

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The soil working levels (SWL) in contaminated soil management are tools used both for carrying out a prompt identification of contaminating elements in exposed areas and for their decontamination as soon as possible.

The data gathered during soil working process can be used during the risk estimating survey. Feasibility survey, decontamination survey as well as in the projects of soil ecological restoration.

Applying some working levels specific to the site involves the development of a land conceptual model (LCM) comprising on one hand collection of some soil parameters, specific to the site (such as apparent density of dried soil and humidity percent) and on the other hand sampling in order to measure the contaminant levels of surface soils and sub soils. Frequently many of such data needed for development of a land conceptual model can be obtained from previous data that is from a preliminary evaluation (PE) and/or from the inspection on the site (IS) [2].

In order to carryout a soil evaluation and an estimation of potential risks for ecological receptors, an ecological survey should be worked out, as part of the remedy investigation/feasibility survey (RI/FS).

3. APPROACHING MODEL FOR A SOIL QUALITY ESTIMATE

In the process of soil quality monitoring, like in contaminated soil risk estimate a step approach can be used that implies the following stages:

1. Developing a land conceptual model (LCM),
2. Comparing the LCM with SWL scenario,
3. Defining the data collecting necessity,
4. Soil sampling and analyzing the soil on site,
5. Computing the SWLs specific to the site,
6. Comparing the contaminating element concentrations of the site soil with computed SWLs,
7. Determining the site areas that need a later survey.

3.1. First stage: Developing a land conceptual model implies the following activities:

a) Collecting the existing data on the land (previous notes, aerial photographs, maps, PE/IS data (preliminary estimate/inspection on site), available basic information, soil surveys etc).
b) Organizing and analyzing the existing data from the site
   b_1) Defining soil functions and setting up soil processes associated to these functions from site
   b_2) Identifying the known contamination sources
   b_3) Identifying the affected environments
   b_4) Identifying potential migration ways, exposing routes and receptors
   b_5) Identifying high sensitivity properties and indicators which are modified following the processes occurred in soil
c) Making up a preliminary diagram of LCM
d) Carrying out a site exploration
   d_1) Confirming and/or modifying the LCM
   d_2) Identifying the missing data
e) Developing a conceptual model on the site involves a series of activities aiming to collect, analyze and expose information obtained from the analyses carried out on site
f) One of the most important aspects of the LCM developing process is to identify and characterize all the potential exposure routes and all the receptors in site by considering the site conditions, the relevant exposing scenarios and the contaminating element properties present in the soils of the site.
g) Equally important is also the making up of a hydro-geological frame that is defined as a unit with common hydro-geological characteristics having a common vulnerability on contamination that is relevant in quality determination.

Also for making evident the information necessary for application of soil exploration, a correlation between relevant exposing routes, site conditions and contaminating element properties of the soil should be made.

It must be known also:

a) Characteristics of the soil contaminating source determining the investigator to collect information on source characteristics including the level of soil contaminating elements and physical and chemical parameters of soils from site necessary for SWLs. This information is systematized for each source in the form of individual data sheets/forms and should be updated after each sampling.
b) The average humidity content in soil (θ_w) defining the fraction of the soil total porosity containing water and respectively air. This parameter is necessary for determining the volatilisation factor (FV) and the saturation rate with water of the soil (C_{sat}).

The average water content (volumetric) in soil can be estimated with the following relation developed by Carp and Hornberger (1978):

$$\theta_w = n\left(\frac{I}{K_s}\right)^{1/(2b+3)} \qquad (1)$$

Where:

n = soil total porosity (m^3_{por}/m^3_{sol})
I = infiltration rate (m/year)
K_s = saturated hydraulic conductivity (m/year)
b = exponential parameter specific to soil (unitary)

The soil total porosity (n) is estimated from the volumetric density of the dried soil (ρ_b), as follows:

$$n = 1 - (\rho_b / \rho_s) \qquad (2)$$

Where:

ρ_s = soil particle density

$$\rho_s = 2.65 \text{ kg/m}^3 \qquad (3)$$

The values for K_s and the exponential term 1/(2b+3) are illustrated in Table 1 by the soil texture class.

Table 1. Estimation of parameters used for computing the average soil humidity content (θ_w)

Soil texture	***K_s (m/year)***	***1/(2b+3)***
Sand	1830	0.090
Loamy sand	540	0.085
Sandy loam	230	0.080
Silt loam	120	0.074
Loam	60	0.073
Sandy clay loam	40	0.058
Silty clay loam	13	0.054
Clay loam	20	0.050
Sandy clay	10	0.042
Silty clay	8	0.042
Clay	5	0.039

By means of data and information obtained in this stage, it can be worked out a diagram of a conceptual model of contaminated soils[1].

3.2. The second stage: The comparison of the LCM with the exploring scenario of soils includes the following activities:

a) Identifying as soon as possible the contaminating sources and the conditions in which the exploring levels of soils are not applicable. This is very important as may be helpful in planning some new strategies of sampling.

b) Identifying the potential routes of exposure to contaminating elements in the soil as follows:

b_1) Direct swallowing

b_2) Inhalation of volatile substances and dust

b_3) Swallowing of contaminated ground water produced by migration of soil chemical substances to the potable aquifer layer

b_4) Dermal absorption

b_5) Swallowing of vegetal products that were contaminated by plant absorption

b_6) Migration of volatile compounds in sub-soils.

c) Working out a survey specific to the site under the following terms:

c_1) The site located near a surface water where the contamination potential and/or flow or release of ground water into surface water should be considered.

c_2) There are potential ecological terrestrial and aquatic hazards.

c_3) There are other possible exposure routes for human beings that were not considered (such as: local fish consumption, cattle farms or other animals)

c_4) There are special conditions in the site such as the presence of liquids in non-aqueous phase (LINP), extended contamination areas, very high levels of dust in the air because of the soil plowed for agricultural use or heavy traffic on unpaved roads.

c_5) There are in the site sub-soils carst rock, aquifer layers of cracked rock or a contamination extending under the water table.

3.3 The third stage: Defining the data collecting necessity in order to identify the site areas surpassing the SWLs which comprises the following activities:

a) Development of a hypothesis regarding the soil contamination distribution (that is what area of the site has a soil contamination surpassing the corresponding SWLs)

b) Development of a sampling and analyses plan in order to determine the soil contaminating element concentrations

b_1) Development of a sampling plan (SP) containing strategies for: sampling and measurement of soil characteristics (volumetric density, humidity content, organic carbon content, porosity, pH).

b_2) Analysis of obtained data and identification of the missing ones specifying the conditions of collecting data specific to the site.

c) Determination of suitable analysis methods in site and setting up the AQ/CQ protocols.

d) The use by the experts of a systematic process of planning the DQO data (data quality objective) in order to support the decision making within the specialized board, a process that is developed in stage and is specific for surface soils and sub-soils. This is schematized in figure 2.

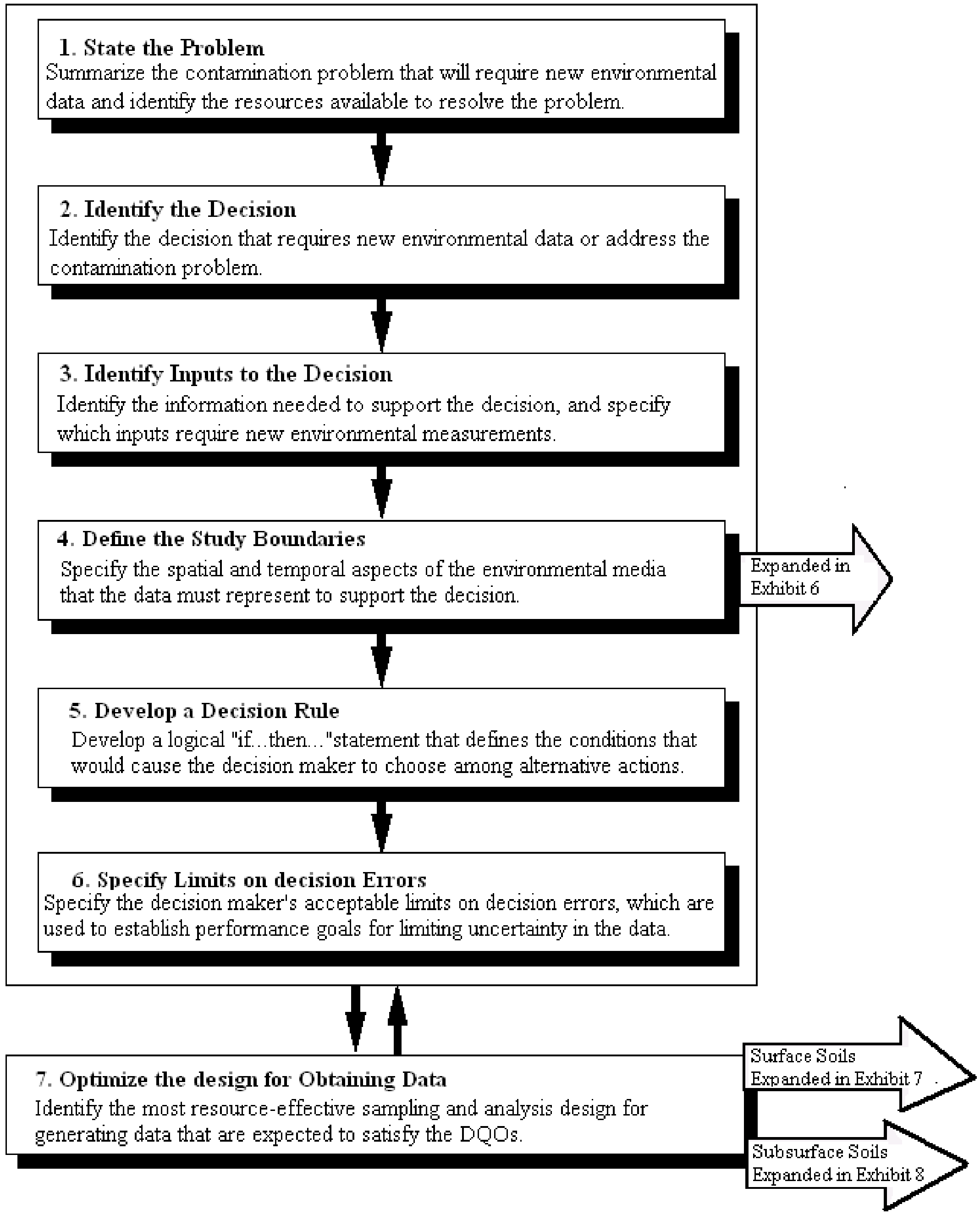

Figure 2. The process of data quality objectives (DQO)

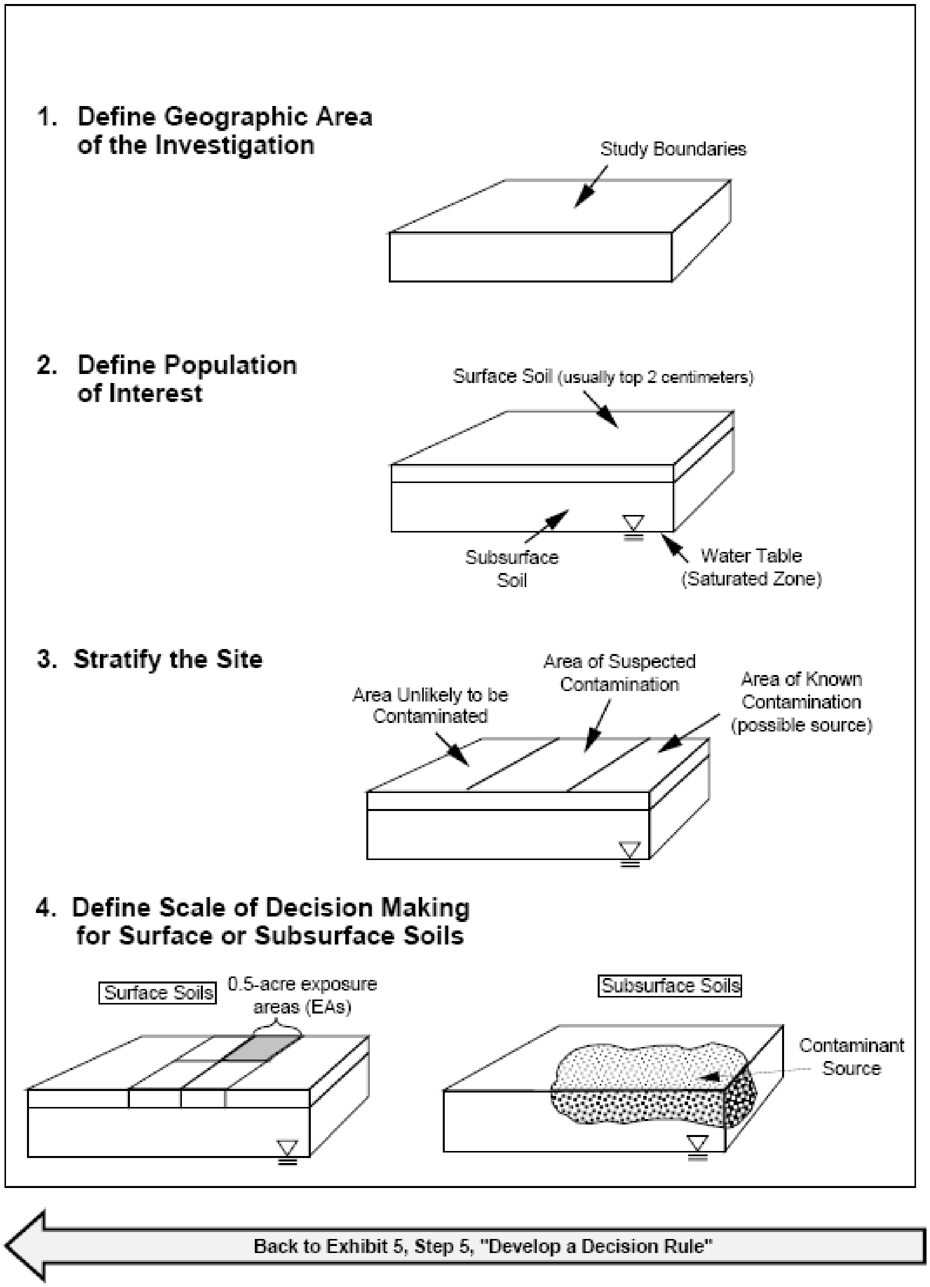

Figure 3. Defining the survey borders

Figure 3 shows the process of defining the survey borders with stratifying the site in three area types requesting different levels of investigation such as:

a) Less probable areas to be contaminated
b) Known areas to be very contaminated
c) Areas that can be contaminated and can not be solved

The less probable areas to be contaminated, in general, do not need later investigations in case the previous information on the site is exhaustive and accurate and confirms this presumption. These are surfaces of the site that were undisturbed in any way by polluting generating activities.

The sampling strategy is very important for the areas that can be contaminated. The known areas to be contaminated, based on existing data, should be investigated and characterized in RI/FS (remedy investigation/feasibility survey).[3]

3.4. The fourth stage: Sampling and analyzing the soils in the site include:

a) Identification of contaminating elements
b) Delimiting the area and source depth
c) Determining the soil characteristics

Then, the LCM is reviewed to correspond to the developed and implemented sampling strategies. The samples shall be analyzed in compliance with the laboratory and on site analytical methods specified in the analysis and sampling plan (ASP). The results of analyses should identify concentrations of potential contaminants for which site specific SWLs should be computed.

3.5. The fifth stage: Setting up the SWLs specific to the site if it is only necessary. This comprises:

a) Identifying SWL equations for the relevant routes
b) Identifying the chemical substances aiming to dermal exposure and plant absorption
c) Obtaining the input parameters specific to the site from the LCM summary
d) Replacing variables of the SWL equations with site specific data
e) Computing SWLs by analyzing the exposure of multiple contaminating elements

3.6. The sixth stage: Comparing the contaminating element concentrations of the site soil with computed SWLs involves a set of activities such as:

a) For surface soils, exposure areas are identified where all the compound samples do not surpass two times the SSLs
b) For sub-soils, areas are detected where the average concentration does not surpass the SWLs
c) Estimating if the soil basic levels surpass the SWLs

3.7. The seventh stage: Decision making regarding the need of some later surveys:

a) Taking into consideration the possibility that some areas need more data
b) Filling in data on soil with other information sources in estimating the site risk
c) Setting up the remedy plan
d) Using the SWLs as PRT (preliminary remedy target) [5].

CONCLUSION

A good management of the contaminated soils involves simultaneous satisfaction of two basic conditions:

a) The efficient use of soil resources for the benefit of human development and
b) Preservation of soil sources based on their importance depending on the ecosystem support

A basic component of the contaminated soil management is represented by estimating the human activity impact on soil, a tool with double utility: for planning and for decision making.

In contaminated soil management, a full strategy should be applied considering the following: all the functions the soil could have, its complexity and variability, degradation processes and social-economical aspects intervening in determining soil quality. The final aim of the contaminated soil management is to improve and preserve the quality by obtaining some positive effects in their evolution.

The presented conceptual model is very complex and useful in analyzing and in ecological recovery of polluted sites.

Acknowledgments

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