SYSTEM TO SUPPORT DECISIONS ON CLEAN-UP OF POLLUTED LANDS

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Keywords: Clean-up Strategy, Map-orientated Analysis, Hydrogeological Foundation, Measurement Values, Pumping Wells, Plane Filtration, One-dimensional Transport of Substances, Multiphase Flow, Soil Monitoring, Hierarchical Closed-loop Controlling System

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Summary

Polluted land areas are large in all parts of the world. These places are a danger for humans both directly, as well as indirectly by the vegetables that are used as animal food. Therefore large areas are unsuitable for the production of agricultural food. Especially in the developing countries, where a lot of people are undernourished, there are not enough places for agriculture. To realize and to optimize the processes of clean-up of polluted lands it is more efficient to use a decision-support system. The human potential of experts alone is not sufficient to prepare for decisions thoroughly. Therefore it is necessary to develop a decision-support system by utilizing the possibilities of modern computer hardware and software.

1. Introduction

In the countries with a high level of industrial production there exists a large area of polluted lands. That makes sense to most people. But in the so-called developing countries a large area of polluted lands exists, too. The problem is that the people in the developing countries do not have such a good environmental awareness and often they have no knowledge about hazards of materials. Also in the developing areas a lot of military action has taken place with a lot of production and storage of chemical hazard material. Also the armaments consist of a lot of hazard substances. Also the waste of man and domestics animals are frequently stored in nearby flat regions or used as fertilizer for agriculture production.

2. Questions on Cleanup Strategy

Polluted land is a very complex topic. In a multitude of cases the land can be contaminated by a wide range of substances. The direct effect on the people is the criteria for the danger of the pollution, but the pollution route through the food chain also plays an important role. In this case, the buildup of pollution concentration is the biggest problem.

In the follow article we will concentrate on contaminated sites and landfill deposits and the routes of pollution in soil and groundwater.

The danger substances existing at the surface or in the soil or groundwater zone varies more by different processes at work, such as dispersion or convection. However, cleanup of polluted lands is possible by removing contaminants, converting dangerous substances into non-dangerous substances or by removal of the substances.

Taking into consideration the importance for regional planning, the following specific aspects have been investigated:

- human health;
- water (groundwater and surface water);
- legally defined protection zone (ecosystems);
- material goods.

To assess the hazard situation it is needed to create a model. The model's aim is to make a complicated state of affairs understandable and provide scientific substance to a long-term legal framework. The model includes these stages:

- tracing those areas from which danger arises, and evaluating the hazard situation;
- setting priorities for the respective hazard situation.

By these means it is possible to gain support for a clearance framework plan arising from a series of individual measures. By setting priorities, individual measures can be carried out as mosaic pieces, without departing from the overall concept. This process is divided into the following individual stages:

- derivation of hazard classes;
- classification of the hazard classes;
- weighting the hazard classes according to the toxicity of the substances present;
- setting priorities, taking into consideration the importance of the medium to be protected;
- grading the priorities, depending on the amount of pollutant.

The determination of the hazard situation first rules out those areas or properties, from which we can assume (with a high degree of probability) that no danger will arise for the environment. As a rule, an environmental danger situation, and any protection and cleanup that might be necessary, depends on a standard value being exceeded. With concentrations of substances in the soil which can only be evaluated using the Dutch list, a test can be made in individual cases to discover which level of pollution above the C-value can be tolerated.
With suspect objects or areas or in those cases where the test value has been exceeded, a test can also be made on the basis of further criteria to assess the level of danger.

To determine the measures to be taken, the danger to the environment is categorized into four levels:

- Contact medium highly contaminated by pollutant; the danger limit has been exceeded; a dangerous exposure of the environmental medium has already occurred.
- Contact medium contaminated by pollutant; the danger limit has not been exceeded; exposure of the environmental medium can be shown to have already occurred.
- Pollutant shown to exist in the contact medium but not on the transport path; an exposure of the environmental medium can be envisaged.
- No proof of contamination by pollutant either on the transport path or in the contact medium; a potential for exposure of the environmental medium exists.

The degree of danger is divided into the hazard classes A, B, and C, with A representing the highest danger level. It comprises stages 1 and 2 on the above scale, as the pollutants are already present in the environmental medium. Class B corresponds to stage 3 and Class C to stage 4.

With regards to the safety of the hazard records, the probability of damage arising at the environmental medium is the decisive factor. Due to the complicated relationships involved in the estimation of hazard situations, and in many cases due to a lack of proof of the conditions, this can only be given with difficulty. Generally, the hazard classes as drawn up (depending on the exposure of the environmental medium) can be assigned as follows: The highest possible probability of damage exists in hazard class A. In hazard class B, a danger to the environmental medium to be protected cannot be ruled out—thus, there is a definite probability for pollutant entry. Hazard class C describes a potential danger situation where the entry of danger to the environmental medium lies between just likely and unlikely. We thus have the following order:

- Hazard class A: Exposure of the environmental medium has occurred; the chance of damage to the environmental medium is probable to very probable.
- Hazard class B: Exposure of the environmental medium foreseeable; the chance of damage to the environmental medium is between just possible and probable.
- Hazard class C: Potential for exposure of the environmental medium; the chance of damage to the environmental medium lies between improbable and just possible.

Priorities are set according to hazard classes A to C and on the basis of the importance of the environmental medium to be protected. Because of the high emphasis given to "human health" in the waste laws, a further differentiation has been made between two levels of importance:

- human health;
- resource-managed water, material goods, and environmental media which are legally obliged to be protected.

Thus, one ends up with these five measures for environmental protection. These represent a rough guide to the urgency of measures.

In order to differentiate priorities at a further level, we adopt the criteria of :

- pollutant toxicity;
- amounts of pollutant that are released and which can spread.

In setting hazard class priority, the pollutant toxicity potential has to be taken into consideration. Depending on the likelihood of release, the amount of pollutant that can contaminate the contact medium (water, soil, air) also has to be considered. Against this background, the optimum priority can generally be given to waste dumps and deposits on contaminated sites.

Toxicity is divided into three classes:

- I extremely toxic;
- II highly toxic;
- III toxic.

The amount of pollutant is classified into four categories: "very high," "high," "medium," and "low."

For the cleanup of polluted materials, different methods are used. Off-site methods involve the removal of the polluted materials. On-site methods involve underground treatment with such methods as pump-and-treat, in which an artificial groundwater flow is produced and the plume with the hazard substances is extracted from the groundwater. By filtering with activated carbon, UV-radiation, electronic beam, stripping method or the like, the pollutant is removed from the water. The cleaned water would normally be infiltrated back underground. In recent times a subsurface treatment method has also been used, the so-called reactive systems (e.g. funnel and gate systems). In this case, we have a self-regulation system that is self-supporting. These systems are independent and permanently working systems without any energy influx. They operate because of the natural groundwater flow: the plume is moved through the gate that contains a chemical filtering system, e.g. iron substrate or organic materials, depending on the pollutant which should be removed.

Historically, the first method of clean-up strategy was mostly adopted, but today the method of natural and enhanced natural attenuation of pollution has come to the fore.

The complexity and financial constraints necessitates the use of modern methods and technologies.

For deciding alternatives, the correct solution and the method of controlling the natural remedial action, a very good knowledge about the processes in the soil and groundwater zone is necessary. Figure 1 shows a scheme in which it is possible to determine and control the processes in the soil and groundwater zone as part of a modern decision-support system.

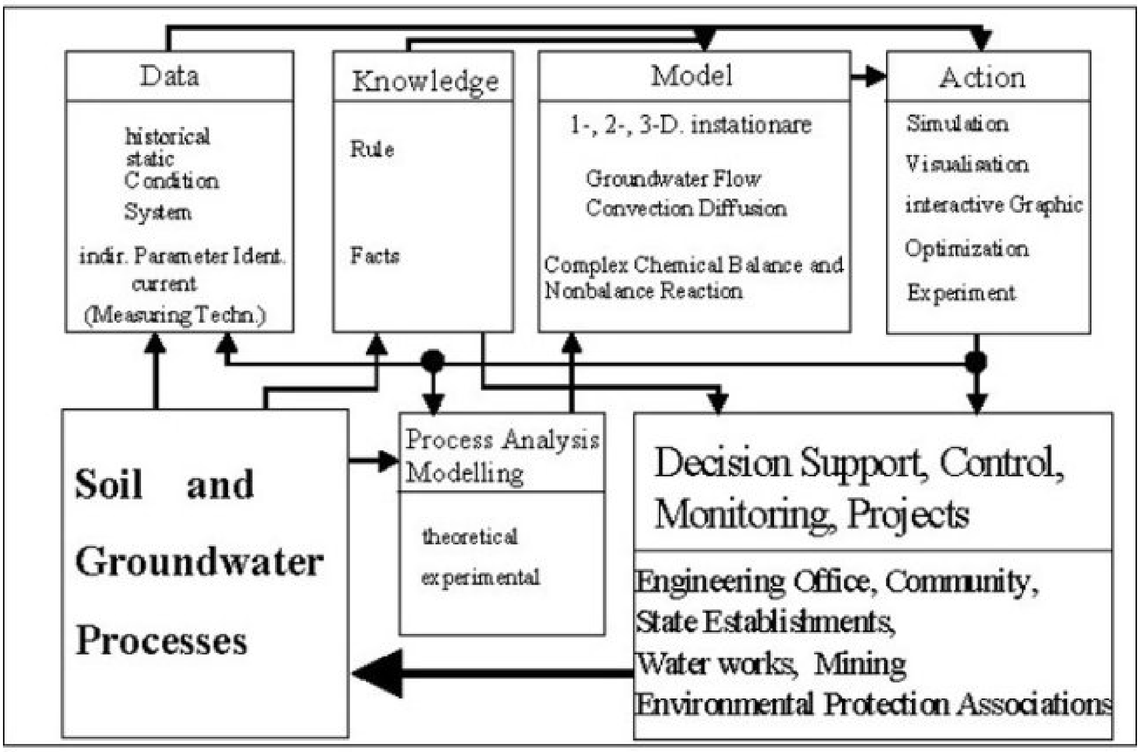

Figure 1. Decision-support system for the clean-up of polluted land.

The database consists of historical and static data. Especially worth considering are the space- dependent data. The data include conditional variables as well as parameters of the soil. The parameters can be estimated by field or lab methods as well as by identification. The conditional variables are obtained from the monitoring system. These variables and the parameters in connection with the space relation are included in the GIS (geographical information system). In the GIS the values are properties/attributes of space points, usually indicated by so-called Gauss-Krueger-coordinates.

The knowledge base is assigned a lot of rules. In most countries laws, regulations and instructions for clean-up technologies exist with environmental protection. The labyrinth of rules restrict the clean-up technologies and at the same time highlight the possibilities of contaminated site treatment. Also a lot of facts describing the danger of the pollutant are usually provided. Often in the past such rules and facts were used alone for the risk assessment of polluted lands. Today more and more this way has been supplemented by a combination of a numerical database and knowledge base criteria.

A lot of decision-support models exist with simple one-dimensional, one-phase, one-substance situations without the means of conversion processes to the highest complex, three-dimensional, multiphase, multi-compartment situations involving chemical reaction and sorption processes.

For the simulation of the processes in the soil and groundwater zone a large range of computer programs exist. Generally, the methods of the solution of partial differential equations (PDE) are divided into different classes:

- by task:
    - solution of the groundwater flow problems;
    - solution of the transport of substances;
    - solution of the inverse problems, the parameter identification;
- by dimension (space and time):
    - 1-, 2- and 3-D;
    - stationary and instationary;
- by water content:
    - saturated;
    - unsaturated zone;
- by mathematical solution methods:
    - analytical solution for the simple groundwater flow relations;
    - numerical solutions, (FDM, FVM, FEM) for the more complex relations;
    - statistical numerical solution (random-walk, particle-tracking) for the simulation of pollution spreading.

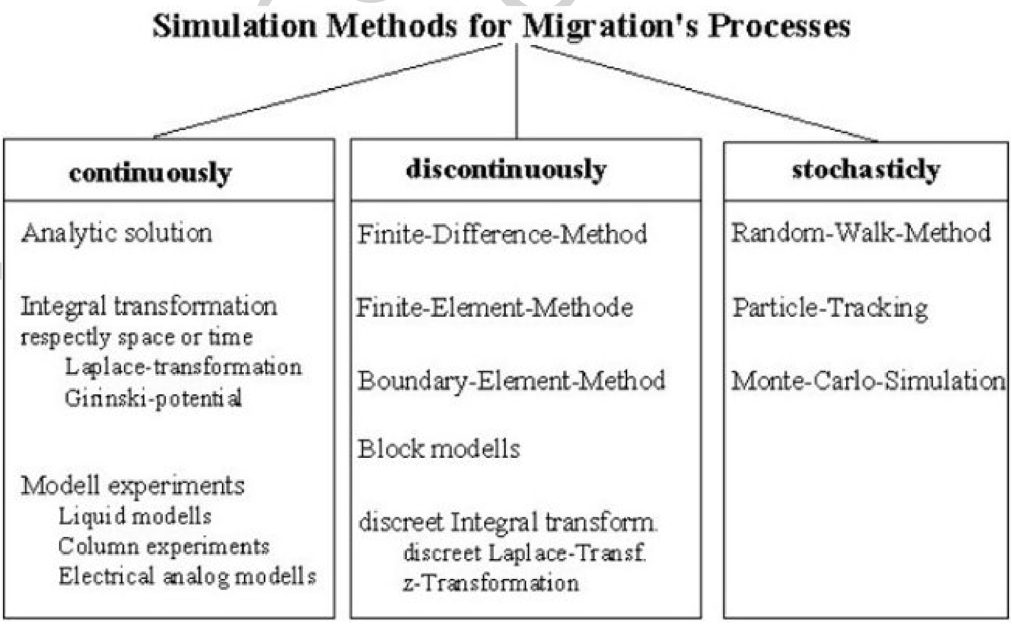

Figure 2. Simulation methods for migration processes.

Figure 2 shows simulation methods for the migration processes. All computations place results into special files such as:

- groundwater level;
- volume quantity flowing through the boundary conditions;
- concentration of substances;
- identified parameters.

The interface between the export of information and the data-processing system is the simulation using visualization, optimization and interactive graphics routines. These can be described as the user/programmer interface (UPI). Such tools are the basics of the decision support system and the control and/or monitoring systems. See: Hazard classes A,B,C, hazard situation, Dutch list, hazard class priorities, filtering, reactive systems, self-regulation system, plume, Geographical Information System (GIS), Gauss-Krueger Coordinates, PDE, groundwater flow problems, transport of substances, parameter identification, stationary and instationary dimension, numerical solutions (FDM, FVM, FEM), statistical numerical solution (random-walk, particle-tracking), simulation, user/programmer interface (UPI).

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Bibliography

Barton, J.; Bilitewski, B; e.a. (1999). *The Protection of European Water Resources*. 356 pp. Brussels:. EC Directorate-General XII, [In this proceedings are a lot of modern and important description of methods for treatment of contaminates sites, landfills, sediments and diffuse pollutions]

Bilitewski, B. e.a. (1997). *Waste Management*, 699 pp. Berlin; Heidelberg: Springer [This book give an overview about the methods in the modern waste management]

Graeber, P.-W. (1999). *Modeling and Simulation of Ground Water Processes*, Process Modelling, Scholz-Reiter,B.; Stahlmann, H.-D.; Nethe, A., pp. 446 – 455, Springer [This paper give an overview about the methods of Modeling an Simulation of the processes in the soil and groundwater zone]

Herbert, M.; Kovar, K. (1998). *Groundwater quality: Remediation and Protection*, IAHS Publication no. 250, 589 pp. Wallingford, UK, IAHS Press [This publication comprises the proceedings of the International Conference on Groundwater Quality in 1998. Of particular interest were: identifications of processes and parameters limiting clean-up efficiency, methods to assess and monitor groundwater quality at field scale, innovative remediation techniques]

Kobus, H.; Barczeski, B.; Koschitzky; H.-P. (1996). *Groundwater and Subsurface Remediation*. 337 pp.. Berlin, Heidelberg: Springer [In this book is intended to provide an orientation for the directions of research strategies for in –situ subsurface remediation by different authors.]

Luckner, L. and Sestakov, V. M. (1991) *Migration processes in the soil and groundwater zone*, 485 pp. Chelsea, Mich.: Lewis [This book present the base of the mathematical modeling of the processes in the soil and groundwater zone]

Puehl, St.; Graeber, P.-W. (1999). *Rule-based Spatial Query and Production as Part of the WHPA*

Simulation, Process Modelling, Scholz-Reiter,B.; Stahlmann, H.-D.; Nethe, A., pp. 545 - 558, Springer [This paper investigates questions of the knowledge base decision support systems for the application in the estimation of groundwater protections zones]

Biographical Sketch

Peter-Wolfgang Graeber is Professor of Systems Analysis and Computer Science in Water Management at the Dresden University of Technology in Dresden, Germany. He received his Dipl.-Ing. (M.Sc.) in electronics and computer engineering and his Dr.-Ing. degree in computer science, as well as the second doctor, Dr.-Ing. habil., in automatic controlling and computer science from the Dresden University of Technology. In 1970 he joined the Faculty of Hydro Science in Dresden, where his research interests include modelling and simulation as well as controlling of water processes, especially in the soil and groundwater zone. Professor Graeber has won numerous experiences in the postgraduate teaching and in the research. He lead several national and international master programs and a lot of research projects. Under him care quit a lot PhD-students got the doctor degree. Above hundred papers and books are written by him. Also he developed above ten patents in him research subject.