Use of ecotoxicological methods for evaluating risks caused by contaminated soils

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USE OF ECOTOXICOLOGICAL METHODS FOR EVALUATING RISKS CAUSED BY CONTAMINATED SOILS

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ABSTRACT

Industrial practices in the past have left a fairly large number of sites where the soil may be higly contaminated by chemicals dangerous for men or for ecosystems, either directly, or through their transport to ground waters.

The evaluation of the initial contamination level and of the relevant risk, as well as the evaluation of the residual risk after rehabilitation ("how clean is clean") are most often based on a complex and erstly analytical approach whose results cannot be easily interpreted in terms of impact on the ecosystem.

The aim of the present paper is to discuss the potential contribution of ecological methods for the global assessment of the risk. General characteristics of soil contamination and of rehabilitation methods are presented as well as the impact on ecosystems and investigation methods based on ecotoxicology. A methodology is proposed and the first results are discussed.

1. INTRODUCTION

The understanding of risks for mankind and for ecosystems created by contaminated soils is a relatively old concept. Regulations concerning the protection and restoration of this milieu, on the other hand, have not been developed to any significant extent.

Considerable research is under way to define methodologies for approaching the problem : evaluation of the extent of contamination and the corresponding risks, definition of criteria for starting rehabilitation operations, definition of quality aims of rehabilitated soil as a function of the projected future use, in response to the question "How clean is clean ?" "i.e." up to what point should we decontaminate ?

The present communication first reviews the main characteristics of soil pollution and its associated risks, and then presents the first results of an approach based on applying ecotoxicological methods for an overall evaluation of toxicity towards ecosystems.

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2. SOIL POLLUTION

Current criteria for declaring a given soil polluted are primarily analytical : a polluted soil is one containing well defined substances at concentrations higher than a level that is currently set in a rather arbitrary manner, for example :

- heavy metals,
- various inorganic pollutants,
- polycyclic aromatic hydrocarbons,
- halogenated hydrocarbons,
- pesticides

The magnitude of the difference between the measured concentrations and the specified levels triggers the intervention, which may be a simple monitoring operation or may go all the way to decontamination. Since the cost of the latter operation can be excessive, we measure to what point it would be useful to reserve decontamination to cases where toxicity is unambiguously demontrated. From this point of view, the analytical approach is insufficient. Knowledge on the toxicity and ecotoxicity of individual substances remains partial and their synergistic possibilities are even less well known. In addition, in a complex medium such as soil, a heterogeneous 3-phase system where a number of physicochemical reactions may occur and, at least down to a certain depth, biological reactions as well, the real toxicity of transformation products is difficult to assess.

Overall tests based on ecotoxicology type bioassays should thus be added to the methods used to evaluate the initial contamination of a soil and the effectiveness of any decontamination efforts made.

3. ECOTOXICOLOGY

Ecotoxicology is the science that studies the toxic effects of chemical or physical agents on living organisms, especially on populations and communities within ecosystems. Ecotoxicology also studies the interactions of these agents with the physical environment in which these organisms live, as well as the transfer pathways of the agents (Butler 1978).

The discipline has a dual aim : to predict the future consequences that can be expected from the release of a given contaminant into the environment, and to evaluate the magnitude of damage to ecosytems following their contamination.

Various methodologies have been developed to attain these aims :

- In the laboratory, test conditions are simplified to their extreme and are strictly standardized to ensure the reproducibility of the results. Each pollutant or each pollutant/species pair is studied alone and the experimental milieu is chosen to be as neutral as possible, except if it is the actual object of the test. Many of these tests are currently standards or are internationally recognized and have been developed primarily to predict the risks related to various steps in the fate of chemicals in the environment.
- Direct effect : acute, subacute, chronic toxicity.

- Biodegradation in aqueous milieus.
- Propensity to bioconcentration (milieu-species relationship) and to bioaccumulation (relationships between species and the food chain).
- Inhibitory effects on reproduction, growth, predation, etc and more generally, behavioral modifications.

The tests involve species belonging to different trophic levels : bacteria, micro-crustacea, fish, worms, mammals, insects, birds ... algae, lichens, higher plants, ...

The extralaboratory aim of ecotoxicology (in the field) is to evaluate the true impact of a local contamination on the animal and plant species dwelling there, in comparison to the state preceding the contamination if it is known, or in comparison to the state of the same type of ecosystem reputed undisturbed. The corresponding approach remains highly empirical and is most often based on criteria of presence/ absence of given species. It may be extended, but in this case costs increase considerably, because of the need for assays of chemical or biochemical markers destined to show exposure to certain toxic agents or their effects.

Between these two extremes of laboratory and field studies exists work whose aim is to improve the representative nature of bioassays, at the cost of increasing complexity in the control of parameters (microcosms, mesocosms, etc).

4. STUDIES CONDUCTED AT INERIS

INERIS has available the means and qualifications for carrying out a number of ecotoxicology tests with respect of Good Laboratory Practices. It is currently working on the validation of an evaluation protocol for soil pollution and the risk of long-distance pollution resulting from it (fig. 1).

The tests carried out are based on standard methods, adapted if necessary to the special cases studied. They involve the soil itself (worm life, germination capacities) and the aqueous extracts obtained by leaching it (bacteria, daphnia, fish, algae, etc).

The soil samples chosen were subjected to detailed physicochemical characterization. It thus becomes possible to determine any potential correlation between overall toxicity as shown by bioassays and chemical composition. The soils tested were sampled from :

- the immediate surroundings of a mixed domestic and industrial waste site,
- a site used to treat wood by impregnation with carbochemistry products,
- soil samples from abandoned coking plants,
- the inert residue of an inorganic material manufacturing process.

The initial results are summarized in table 1. The "Daphnia magna" and "Photobacterium" tests were done on leachates according to standard NF X 31-210 and the "Eisenia fetida" test was done on the soil itself.

The numbers in the different columns represent the percentage of soil or of leachate leading to 50 % inhibition of mobility or of light emission, or 50 % mortality in the population tests.

The observed toxicity is higher as the number is lower.

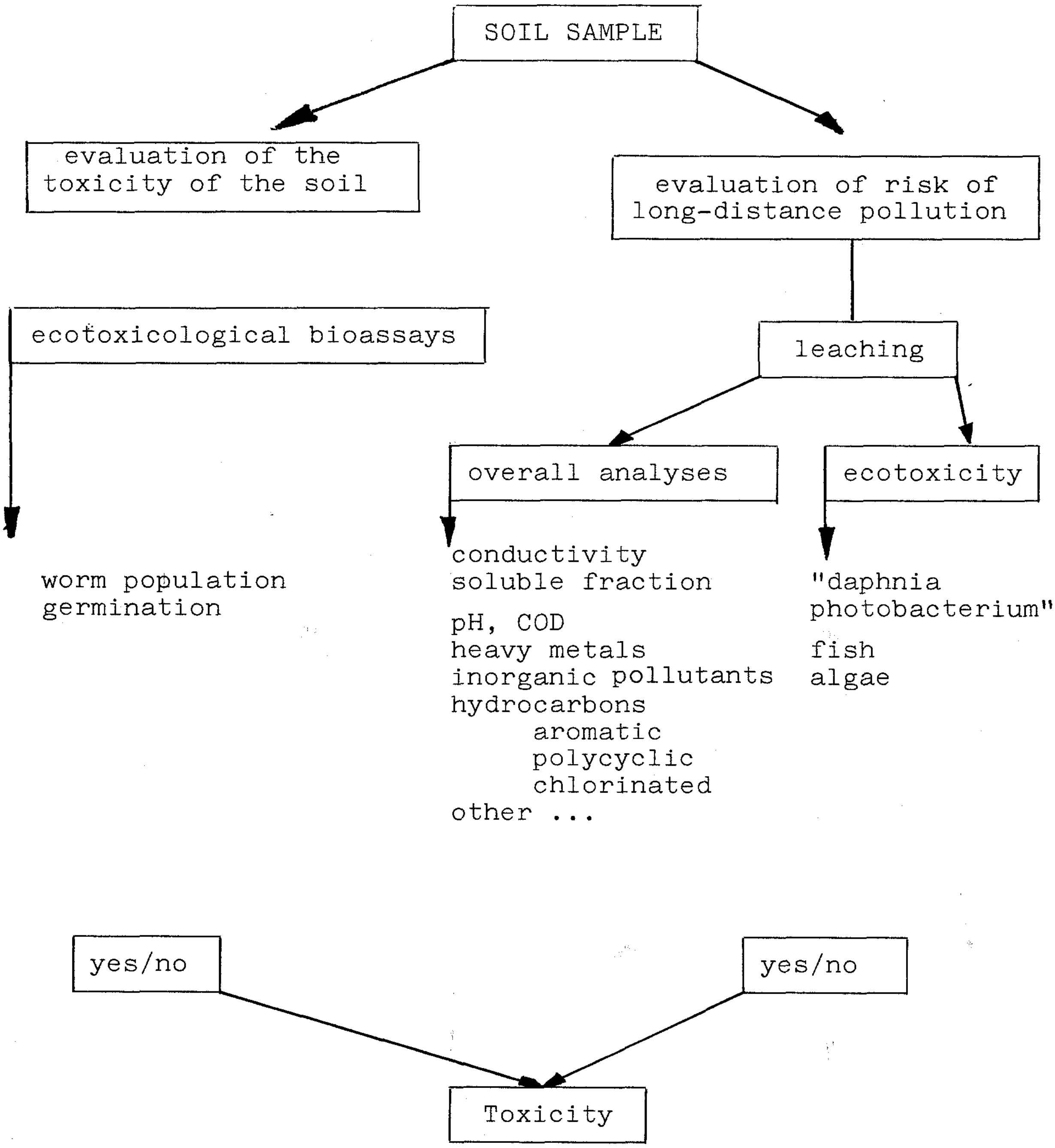
"Tests of inhibition of "Daphnia magna" mobility and of the inhibition of light emission by "Photobacterium phosphoreum" are bioassays that can be used to show phenomena of sublethal toxicity, while the test with "Eisenia fetida" can be used to show a lethal effect directed against this organism".

5. CONCLUSIONS

The initial results are encouraging for the continuation of our efforts, enlarging the battery of ecotoxicology tests to use and the range of soil types to examine. Ultimately, this work should enable us to propose the most relevant and least costly test(s) for screening the toxic properties of soils before starting a series of detailed analyses. The latter, however, will evidently remain necessary if screening brings to light a toxicity justifying decontamination. Only the precise knowledge of the chemical species to be eliminated will enable us to choose the most effective rehabilitation method af the lowest cost.

"In addition, these tests sould enable us to evaluate the effectiveness of a soil rehabilitation method and to respond to the question "How clean is clean ?".

Fig. 1 - Draft for Protocol to evaluate the level of soil pollution



Comments on the table

EC(I) 50 24 h : initial 50 % inhibitory effective concentration in 24 h.
IC 50 15 min : 50 % inhibitory concentration in 15 minutes.
LC 50 14 d : 50 % lethal concentration in 14 days.

TEST SOILS	"Daphnia Magn" EC(I) 50 24 h	"Photobacterium" IC 50 15 min	"Eisenia fetida" LC 50 14 d	Principal pollutants
T & M co-product	non tox	non tox	non tox	non tox
Vlb landfill	non tox	non tox	non tox	ppb
S w 1 wood treatment	non tox	41 %	non tox	HAP ppm
SW 2 wood treatment	70 %	15 %	50 %	HAP g/kg
SW 3 wood treatment	non tox	30 %	non tox	HAP ppm
LV coking plant	80 %	8 %	< 10 %	HAP, BTX, CN,metals
N coking plant	62 %	5 %	< 10 %	HAP, BTX, CN, metals
BRG coking plant	non tox	non tox	non tox	HAP, BTX, CN, metals

At this stage of the research, the results are still too few in number to be able to establish unambiguous correlations. It is to be noted, however, that ecotoxicology tests have a good degree of discrimination.