How can we use the radioecological sensitivity concept as a tool for risk management ?

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Abstract:
The consequences for the man and the environment of the discharges of nuclear facilities depend on the importance and the nature of the discharges, but also on the environment which receives them. Thus, the impact of a pollution, which is expressed in term of toxicity, risk or economic consequences, varies according to the characteristics of the environment and the use of this environment by the man. The radioecological sensitivity can be defined as the response of the environment to a radioactive pollution. For a determined discharge, the higher is the response, the more sensitive is the environment. If all the ecosystems appear sensitive, their sensitivity does not concern the same criteria and it is currently difficult to compare these criteria between them. The idea of the SENSIB project is to create a standardized tool which makes it possible to represent and to compare with the same scale the sensitivity of various ecosystems. The SENSIB project aims to develop both a methodology to calculate sensitivity indexes and a radioecological sensitivity scale usable for risk management.

1 CONTEXT

The impact of industrial pollution on man and the environment depends on the extent and type of pollution, and also on the environment polluted. The economical, toxicological or health repercussions will vary according to characteristics of the environment polluted and the use man makes of the environment.
Thus, the sensitivity of the different environments: urban, agricultural, forest, river, lacustrine, marine or high-altitude, varies depending on the type of pollution. For example, the sensitivity of urban environments is associated with population density, artificial surfaces and other urban amenities tending to concentrate pollutants on some surfaces or matrices. The sensitivity of agricultural lands is the result of pollution of the food chain via contamination of soil, crops and livestock. Wild ecosystems, notably forests, play a recognised role in the persistence of pollutants that are continuously recycled or transformed in these areas. The highest concentrations of toxic substances are frequently found in the plant and animal species in these ecosystems.
Furthermore, within these environments, there are various specific factors, either natural or anthropic, which control the environmental response to pollution. For example, in an agricultural land, the type of farming is a significant sensitivity factor. Wheat and milk produced on a field subjected to the same type of pollution will yield extremely different contamination levels. Persistence of this contamination in successive crops will also be highly dependent on soil characteristics. Generally, all the inherent characteristics of an ecosystem that influence transfer of pollutants, will lead to a specific environmental sensitivity. The same applies to anthropic factors, such as agricultural practices (use of fertilisers, irrigation, sowing period) or livestock farming practises (feeding animals, outdoor pasturing).
Although each environment has a specific sensitivity to pollution, it is difficult to compare these various sensitivities. Is it more harmful to have a stock of pollutants in a barely

anthropised wild ecosystem or to have a high concentration of radionuclides in a watercourse used for irrigation ?
The aim of the "Radioecological Sensitivity" project is to develop a standardised tool that will allow the representation and the comparison of the sensitivity of the various environments to radioactive pollution. The project notably involves enabling classification of various environments based on their inherent characteristics. The expected results are, on one hand, a system of indices allowing overall and opposable evaluation of an environment's sensitivity, and on the other, an operational indexing method that takes into account the influence of multiple environmental characteristics on an environment’s response to radioactive pollution.
As regards possible applications, this tool may be used to produce sensitivity maps, especially around nuclear facilities. By adding a "Risk" component to the "Sensitivity" component, the "Vulnerability" of an environment may be established.
The sensitivity concept may be extended to components other than the environmental component. Thus, parameters associated with human activity, for example, the degree of self-sufficiency, density of human infrastructures, intervention capacity, evacuation possibilities, etc., may also form the subject of classification that may be interfaced with the radioecological sensitivity classification.

2 STAKES

It will be possible to use this standardisation of environmental characteristics to analyse and manage risks for humans and for the environment, at every stage of a nuclear facility's life cycle:

- Prior to start-up: assistance in selecting the site, contribution to the impact analysis (characterisation of the initial condition, vulnerable areas, environmental protection, etc.), assistance in effluent management strategy decisions, etc.
- In normal operation mode: optimisation of emission modes, monitoring strategy, optimisation of sampling, sample representativeness, analysis of the relevance of radiological impact indicators, etc.
- In accidental mode: sampling plan as a function of the type and the characteristics of emission into the environment, etc.
- In post-accidental mode: intervention priority, countermeasures, monitoring, etc.
- In end of activity mode: classification of orphans sites, impact of dismantling works, monitoring of the environment, etc.

One of the major stakes of the project is the achievement of integrated analyses that is to say simultaneous treatment of various environments (terrestrial, aquatic continental and marine). This choice allows many possibilities: characterisation of fluxes within ecosystems, possibility to establish whole balance for a radionuclide, calculation of collective doses combining all contributions from a single facility, optimisation of emissions, etc.
The decision to consider in parallel the various indicators of response to pollution (specific activity, total concentration, flux) also provides numerous possibilities: ease of navigation between individual impact and collective impact, possibility to check coherency between emissions and stocks distributed in the environment, etc.
The concept of sensitivity is frequently presented as being useful for post-accidental management or pre-emergency planning. Standardised and operational classifications, as well as prioritised information and representation tools, are needed in emergency situations. In the nuclear industry, the INES scale allows accidents to be classified according to severity. A similar scale was developed recently in France based on health criteria [1]. Currently, there is no classification scale for environmental criteria. Therefore, significant work is expected in the area of classification in order to finally obtain an environmental sensitivity scale that can be used for post-accidental management.

3 DEFINITIONS

Radioecological sensitivity may be defined as the environmental component that conditions the environment's response to radioactive pollution (Figure 1). This response is embodied through indicators: specific activity or activity concentration, radionuclide stock or flux. For a given emission: the higher the response, the more sensitive the surface. The purpose of sensitivity indices is to provide an overall evaluation of the intensity of an environment's response to a type of pollution.

The intensity of transfer processes that lead from an emission to concentration of pollutants in physical and living environments is dependant on various parameters or factors inherent to the environments. These sensitivity factors, such as climate, physico-chemical, mineralogical and biological characteristics of soils, the use made of these environments, etc. will determine the behaviour of pollutants and in fine the response of the environment.

Although each environment has a specific sensitivity to pollution, it is difficult to compare these various sensitivities. Is it more harmful to have a stock of pollutants in a barely anthropised wild ecosystem or to have a high concentration of radionuclides in a watercourse used for irrigation?

The aim of the "Radioecological Sensitivity" project is to develop a standardised tool that will allow the representation and the comparison on the same scale of value of the sensitivity of the various environments to radioactive pollution. The project notably involves enabling classification of various environments based on their inherent characteristics. The expected results are, on one hand, a system of indices allowing overall and opposable evaluation of an environment's sensitivity, and on the other, an operational indexing method that takes into account the influence of multiple environmental characteristics on an environment’s response to radioactive pollution. As regards possible applications, this tool may be used to produce sensitivity maps, especially around nuclear facilities.

The sensitivity concept may be extended to components other than the environmental component. Thus, parameters associated with human activity, for example, the degree of self-sufficiency, density of human infrastructures, intervention capacity, evacuation possibilities, etc., may also form the subject of classifications that may be interfaced with the radioecological sensitivity classification.

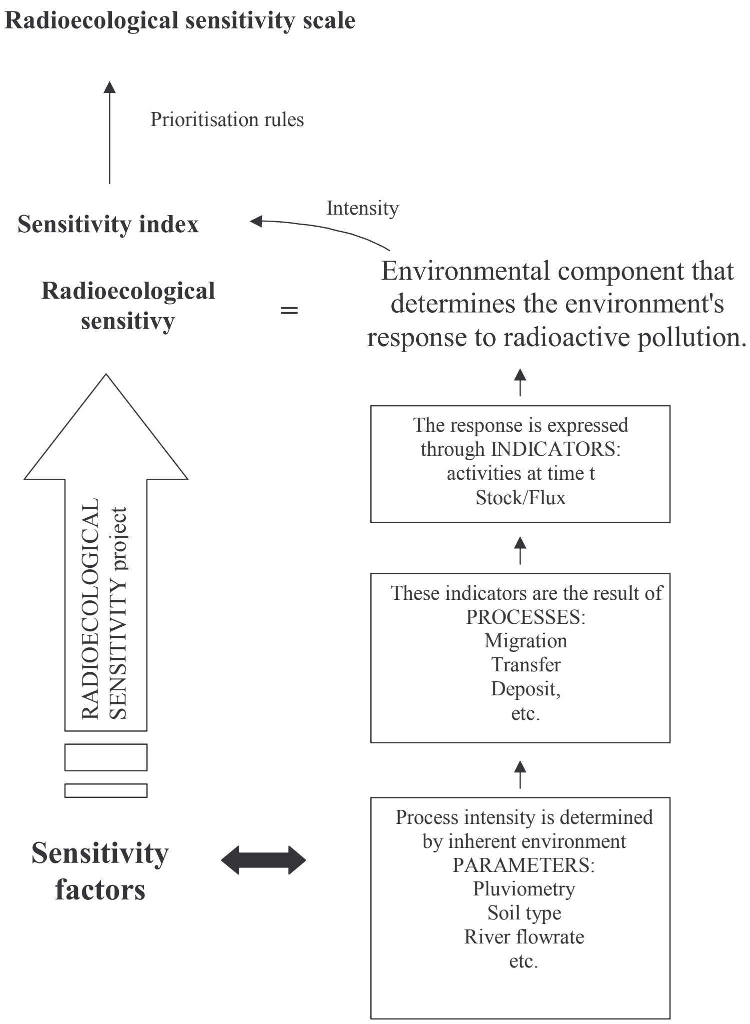

Figure 1: Definition of radioecological sensitivity

4 METHODOLOGY

To determine the relative sensitivity of a surface, factors that control sensitivity and that could modify it, i.e. that could increase or decrease the consequences of pollution, must be analysed.

Before examining these factors, the sensitivity indicators that will be used for this project should be defined. This will involve selecting the most pertinent sensitivity indicators from those listed in literature (aggregated transfer factor, action load, intervention level, radionuclide flux, individual exposure), or defining others. Similarly, work scales in terms of time and space must be defined. As regards time, the project intends to deal with the area of chronic risks and accidental risks. As regards space, it is likely that various scales will be used during the project ("workshop areas", catchments areas, administrative sectoring, etc.). The relevant scales will be selected as the project advances. This will require work to harmonise results from the various project support studies.

Next, the sensitivity factors will be listed. Various types of factors will be identified and classified: ecological parameters characteristic of the ecosystem but independent of radionuclides, radioecological parameters dependent on the radionuclide, anthropic parameters, etc.

During the sensitivity factor characterisation step, the values each factor can take will be determined. Some factors may feature a range of values. For example, the "mean annual precipitation" factor that, in France, can vary between less than 600 to more than 1,800 $mm.year^{-1}$. Others are categorial factors, such as land use: dwellings, forest, grazing, wheat field, etc.
This characterisation work will be performed based on knowledge acquired at IRSN, both in terms of expert analyses and data gathered in the field (use and analysis of the SYLVESTRE database of the IRSN and acquisition of new field data), and on the bibliographic data broadened to include other disciplines through collaboration with other organisations.
An index between 1 and 10 will be associated with each sensitivity factor specifying the advantages or penalising nature of values. As regards the "mean annual precipitation" factor, the index will increase with increasing mean precipitation, if this caused increasing atmospheric pollutant deposition. On the contrary, if precipitation resulted in washout of a surface, the index could decrease. Therefore, it appears that the indexing system could vary as a function of stakes. The indexation step will be the key step of the project and its success will mainly be based on our ability to create a network of experts around the project.

In parallel, the contribution or relative "weight" of each factor to the sensitivity of the global environment will be established by means of a sensitivity analysis covering every stage from emission to economic, toxicological or health repercussions. This contribution may be expressed as a percentage. For example, the "mean annual precipitation" factor could have a contribution of 0.1, a pedological factor a contribution of 0.05, and a land use factor a contribution of 0.2 to the sensitivity of the environment in question. This work will be performed mainly using pollutant transfer models in the various environments.
Hence, environment sensitivity will be calculated by adding the sum of the indices of each factor weighted by its contribution. The figure thus obtained will allow an intercomparison of environments as regards their sensitivity. The higher the number, the more sensitive the environment.
Analysis of usable mapping means and spatialization of results will produce maps illustrating environment sensitivity to a given pollution risk.
Lastly, a sensitivity scale will be developed to standardise comparisons between sensitivity indices.

The main steps of the Radioecological Sensitivity project are illustrated in Figure 2.

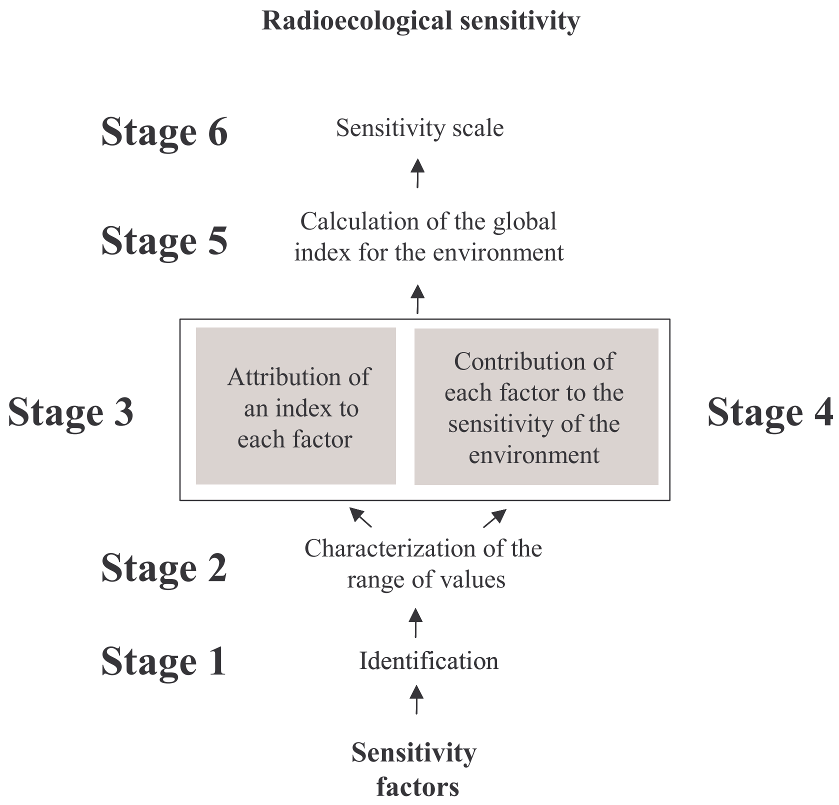

Figure 2: The main steps of the SENSIB project

5 CONCLUSION

The concept of radioecological sensitivity will enable representation of the intensity of an environment's response to pollution. The aim of the SENSIB project launched by the IRSN in 2004 is to make this concept operational by explaining the relationships between environment sensitivity indices and inherent parameters, and, by building tools to represent and determine the hierarchy of these indices. This project should allow the development of environmental classification that could be used when assessing and managing risks for humans and for the environment.

6 REFERENCES

[1] P. Crouaïl et C. Lefaure, Proposition d'une échelle de classement des incidents et accidents radiologiques, Rapport n°276, Centre d'études sur l'évaluation de la protection dans le domaine nucléaire, Fontenay-aux-Roses, France, 2003