Review of the operational use of the concept of sensitivity of the environment

- At the inception of the Radioecological Sensitivity Project (SENSIB, IRSN, France), Mercat-Rommens & Renaud carried out a review of the state of the art concerning the significance and the uses of the concept of sensitivity of the environment.

- Rapport IRSN: DEI/SESURE n° 2004-21, Août 2004.

- The authors (Mercat-Rommens and Renaud) started from the results of the Radioecological sensitivity forum 1998-2001:
  - Howard et al, Radioecological sensitivity final report: September 1998-March 2001, Center for Ecology and Hydrology, Natural Environment Research Council, March 2002.
- Other documents used here:
  - “The concept of radioecological sensitivity” Howard, 2000:
    - the concept of radioecological sensitivity is discussed, with specific reference to the spatial perspective
  - “Estimation of radioecological sensitivity”, Howard et al., 2002
    - the appropriate quantities are defined necessary to define radioecological sensitivity and to consider their temporal and spatial variation

A short history of the “radioecological sensitivity” concept

- Critical groups (ICRP, 1993)
- Radioecological sensitivity (Aarkrog, 1979)
- Vulnerability
- Critical load (Nilsson and Grennfelt, 1988)
- Action loads (Howard et al., 2002)

The first approach used in the area of radioprotection was the:

Identification of Critical Groups, ICRP, 1993

- Critical groups are representatives of the public who are the most exposed to a source
- this identification leads to take into account not only the population dietary habits, but also living habits, management practices and ecological niches (the environment).

From “The concept of radioecological sensitivity” Howard, 2000

Radioecological Sensitivity Aarkrog, 1979

- The Radioecological Sensitivity concept appeared for the first time in 1979:
  - "the infinite time-integrated radionuclide concentration in the environmental sample considered, arising from the deposition of 1 mCi/km^2 of the radionuclide in question"
- The indicator used by Aarkrog:

$$T_{ag} = Ci\ kg^{-1}/mCi\ km^{-2}$$

From: "Estimation of radioecological sensitivity" Howard et al., 2002

The Vulnerability concept

- The Vulnerability concept was used:
- in the framework of the AMAP (Arctic Monitoring and Assessment Programme) Project (Strand et al. 1997),
- and in the framework of the AVAIL (Arctic Vulnerability to radioactive Contamination) programme (AVAIL, 2002)
- demonstrated that the arctic ecosystems were more vulnerable to radiocaesium than the ecosystems of temperate climates

From: Review of the operational use of the concept of sensitivity of the environment, Mercat-Rommens and Renaud, 2004.

The Critical load concept

- was originally developed in response to the impact of acidifying emissions.
- The Critical Load is “A quantitative estimate of an exposure to one or more pollutants, below which significant harmful effects on specified sensitive elements of the environment do not occur according to present knowledge” (Nilsson and Grennfelt, 1988)
- was then proposed as an indicator for the radioecological sensitivity

From “The concept of radioecological sensitivity” Howard, 2000

The critical load as indicator in radioecology:

- the level of r.n. deposition ($Bq \cdot m^{-2}$) which leads to activity concentrations in a food product above intervention limits at a given time after deposition.
- initially developed using $T_{ag}s$ ($Bq \cdot kg^{-1}$)/($Bq \cdot m^{-2}$) (Wright et al., 1998)
- incorporated within semi-mechanistic models (Howard et al., 1999, SAVE)
- widely used (Eriksson, 1997, Iosjpe et al., 2002, ARMARA)

From “The concept of radioecological sensitivity” Howard, 2000

The Radioecological sensitivity forum discussed and proposed four Indicators of radioecological sensitivity:

- Aggregated transfer coefficients (T_{ag})
- Action load
- Fluxes
- Individual exposure of humans

From: “Estimation of radioecological sensitivity” Howard et al., 2002

1. Aggregated transfer coefficient T_{ag} ($m^2 \cdot kg^{-1}$)

- Activity concentration into an environmental compartment ($Bq \cdot kg^{-1}$) divided by the corresponding radionuclide deposition ($Bq \cdot m^{-2}$).
- Indicator useful for:
  - food products
  - sensitivity analysis of biota
- T_{ag} are time dependent and can be combined with ecological half-lives to quantify changes with time.

From: “Estimation of radioecological sensitivity” Howard et al., 2002

2. The Action load

- derived from the critical load concept
- Critical loads, developed for the mid-long term phase, were renamed as action loads for the acute phase after an accident.
- the “Action load” (level of intervention):
  - the level of deposit (in $Bq \cdot m^{-2}$) from which the intervention (countermeasure) must be envisioned as the food contamination limit is exceeded.
- Maps of action load for different food products can be combined with maps of deposition for the rapid identification of areas that are either sensitive or resilient after deposition.

From: “Estimation of radioecological sensitivity” Howard et al., 2002

3. The Flux

- is the total quantity of radioactivity produced in a specified environmental product over a given period of time (Bq y^{-1}), which is transferred from one compartment to another.
- To evaluate collective doses, agricultural production statistics need to be incorporated.
- Used in several surveys on the continental environment (Camplin et al., 1989) and on the marine environment (Iosjpe et al., 2002).

From: “Estimation of radioecological sensitivity” Howard et al., 2002

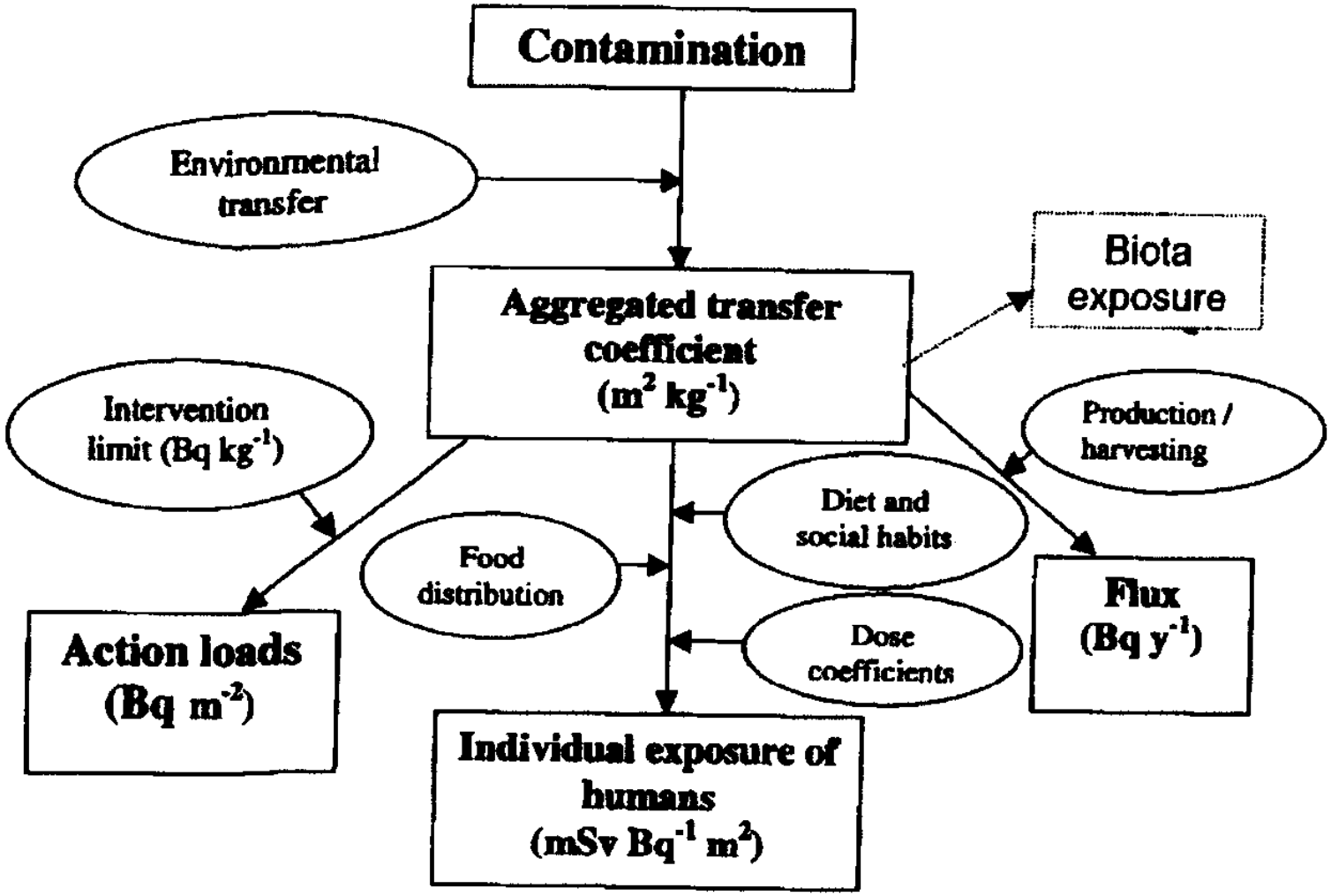
4. Exposure to humans

- the individual exposition: mSv/ $Bq \cdot m^{-2}$
- This concept is close to that of the aggregated transfer coeffficient but also includes the individual behaviours of the population surveyed:
  - dietary habits
  - where the food comes from
- In general, self-sufficiency with respect to diet and food production tends to increase radioecological sensitivity.

From: “Estimation of radioecological sensitivity” Howard et al., 2002

The four radiological sensitivity indicators

From: “Estimation of radioecological sensitivity” Howard et al., 2002



Temporal and spatial variability need to be considered

- temporal variability due to:
  - physical half-lives
  - biological half-lives
  - ecological half-lives
- spatial variability due to variation in:
  - ecosystem characteristics
  - human utilisation of resources

From: “Estimation of radioecological sensitivity” Howard et al., 2002

Radioecological sensitivity is radionuclide specific

- some r.n. are environmentally mobile:
  - Cs, Sr, I
- some r.n. have high accumulation factors for certain biota
  - Tc transfer to lobsters
  - Ru/Tc transfer to seaweed
- some r.n. have high radiotoxicity
  - alfa emitters

From “The concept of radioecological sensitivity” Howard, 2000

Criteria for radioecological sensitivity (Howard, 2000)

Focus on identifying:

- Pathways
- Habits (for humans or biota)
- Location
  - spatial variation
  - sensitive areas = more likely to be contaminated
- Habitats and communities
  - sensitivity considered with respect to ecosystem functioning

From: “Estimation of radioecological sensitivity” Howard et al., 2002
From “The concept of radioecological sensitivity” Howard, 2000

Enhanced exposure can arise from a number of different reasons:

- high r.n. accumulation
  - high biomass concentration
  - high precipitation rates
  - proximity to radiation sources
- sustained retention in certain environmental compartments
  - long biological or ecological half-lives
- high bioavailability
  - high uptake from soil
- interaction with ecosystems
  - dietary habits
  - occupancy habits
  - agricultural practices

From: “Estimation of radioecological sensitivity” Howard et al., 2002

Important points: Howard et al., 2002

- There is the potential to consider sensitivity with respect to doses to biota, but the focus has thus far been restricted to a consideration of human exposure.
- Radioecological sensitivity should be applicable to practices (as part of pre-planning), as well as interventions (in identifying priorities after an accident).
- Radioecological sensitivity can be introduced as part of emergency preparedness.

From: “Estimation of radioecological sensitivity” Howard et al., 2002

Spatial variation

Key factors which vary spatially:

- Transfer (varies f.i. with soil type)
- R.n. migration (catchment characteristics, f.i. associated with organic soils)
- Land use (f.i. fertilisation rates, animal management strategies)
- Production (areas may be considered to be sensitive, if they produce large quantities of food products)
- Dietary habits and consumption (wild foodstuffs)
- Economic, ecologic and social value (areas particularly productive, protected areas,)

From “The concept of radioecological sensitivity” Howard, 2000

Temporal considerations

- the relative radioecological sensitivity of ecosystems and products will vary with time: f.i.
  - areas producing milk contaminated by short half-life radionuclides are the most sensitive over short time periods
  - soil-plant uptake will affect sensitivity over longer time periods

From “The concept of radioecological sensitivity” Howard, 2000

Radioecological Sensitivity Forum: Intervention levels for the terrestrial environment

- were calculated by ECOSYS, AGROLAND and SAVE-IT (Howard et al., 1999).
- Various scenarios:
  - source: Cs, Sr, I, Pu
  - acute (?) dry or wet deposition
  - at different dates (1st May, 1st August, 1st October)
  - soil type: clay, sand, peat
  - end point: cow milk
- Results show differences due to the geographical specificities of the models.

From: Review of the operational use of the concept of sensitivity of the environment, Mercat-Rommens and Renaud, 2004.

Radioecological Sensitivity Forum: Intervention level prioritisations:

- $^{90}Sr < {}^{131}I < {}^{137}Cs < Pu$
- For ^{137}Cs: peat < sand< clay
- For ^{90}Sr: clay < peat < sand

From: Review of the operational use of the concept of sensitivity of the environment, Mercat-Rommens and Renaud, 2004.

Radioecological Sensitivity Forum

- Other Scenarios discussed:
- aquatic environment:
  - end points: drinkable water, fish
- marine environment: surface deposition

From: Review of the operational use of the concept of sensitivity of the environment, Mercat-Rommens and Renaud, 2004.

Sensitivity of the environment

- significance
- uses

From: Review of the operational use of the concept of sensitivity of the environment, Mercat-Rommens and Renaud, 2004.

Aim of the radiological sensitivity project

- to develop a standardized tool that will allow the representation and the comparison of the sensitivity of the various environments to radioactive pollution.

- The objective of SENSIB is to deal with the environment on a more global scale.
- in order to obtain an environmental sensitivity scale.

From: Review of the operational use of the concept of sensitivity of the environment, Mercat-Rommens and Renaud, 2004.

Polluted site methodology: a simplified risk assessment method

- BRGM (2000). Gestion des sites (potentiellement) pollués, classeur-guide version 2, editions du BRGM, Orléans, France.
  - (BRGM is the French institute of geosciences for a sustainable earth)
- Three components are envisaged:
  - a source
  - a transfer pathway
  - a target
- each component is characterized using a marking system based on the combination of marks representing the contribution of different parameters.

From: Review of the operational use of the concept of sensitivity of the environment, Mercat-Rommens and Renaud, 2004.

Polluted site methodology: Factor categories

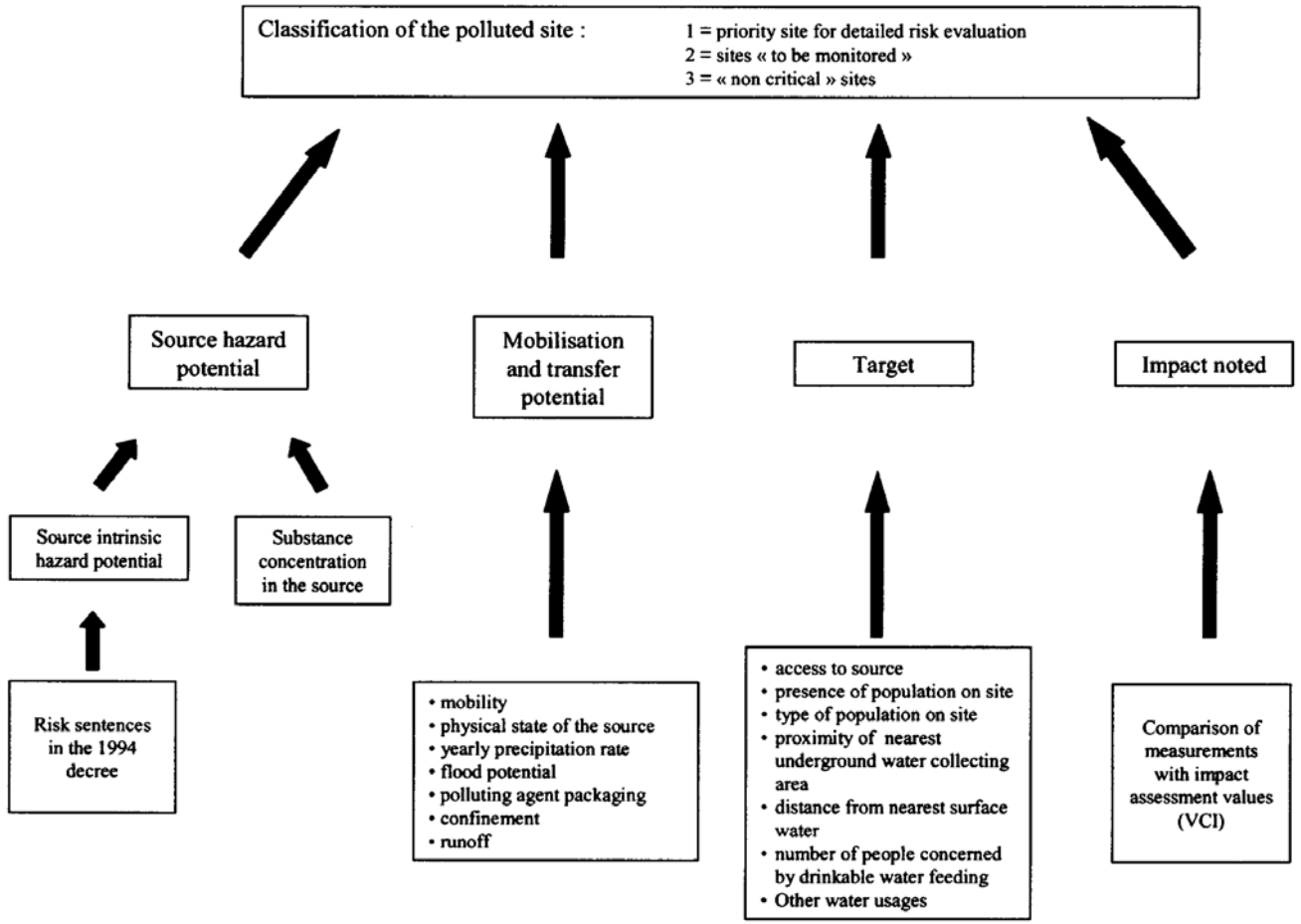
43 parameters were distributed in four factor categories:

- the source hazard potential
- the pollutant mobilisation and transfer potential
- the target (underground water, surface water, soil)
- the impact noted

- Each factor is subject to specific marking modes (0→3 and eventually “?”)
- The grades given to each factor are combined for each of the targets retained in the evaluation.
- The simplified risk evolution corresponds to a tree structure that allows to take into account the multiple criteria in the definition of the final mark given to a polluted site.

From: Review of the operational use of the concept of sensitivity of the environment, Mercat-Rommens and Renaud, 2004.

Polluted site methodology tree structure, proposed in the BRGM guide file (2000)



From: Review of the operational use of the concept of sensitivity of the environment, Mercat-Rommens and Renaud, 2004.

- The sensitivity could come from a high variability of the value of the parameter at the European scale or of the high contribution of a parameter in dose calculation or of a social high sensitivity …

PRIME Project in France: multicriteria and stakeholders involvement to characterize, in a collaborative way, contaminated lands

- The aim of PRIME Project is :

  « to develop a method of multicriteria analysis for characterisation of the contaminated area. The method will be elaborated through the participation of experts, decisionmakers and local actors in order to enable the risk managers to choose the appropriate strategy in case of an accident involving radioactive substances.

IAEA
Suggested new topics

- The new programme should reflect current developments in the fields related to environmental radiological assessment modelling. Some of these are:
  - The new ICRP Recommendations and, in particular, the shift from “critical group” to “representative individual”.
  - Climate change and the implications for the future of nuclear installations.
    - types of hypothetical climate change scenarios, e.g. sea level change, desertification.

Da IAEA views

- Emergency:
  - Consideration of “environmental sensitivity” in assessment modelling