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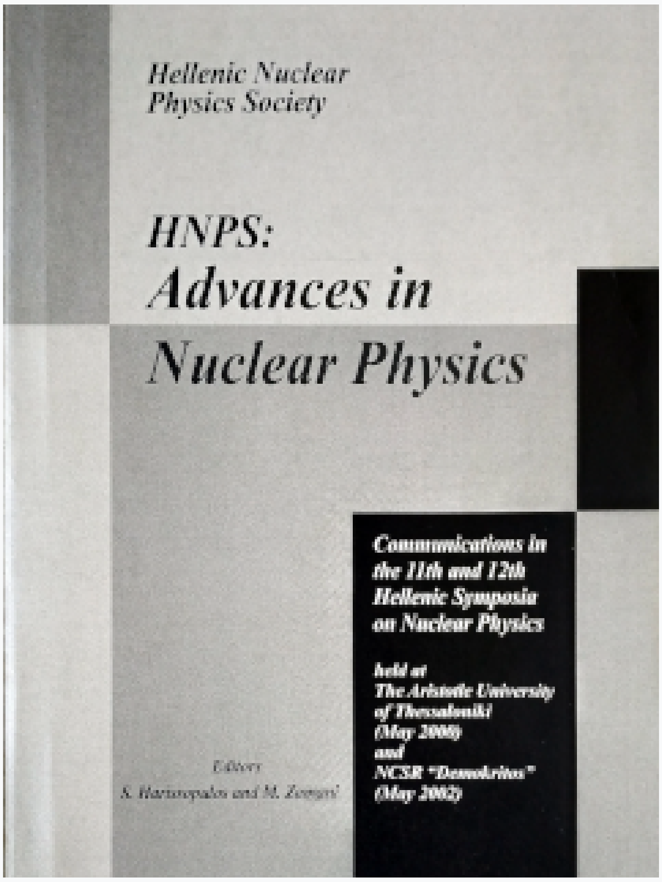

The Introduction of a new physical quantity and a corresponding scale for measuring the Radioecological Sensitivity of a certain area

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The Introduction of a new physical quantity and a corresponding scale for measuring the Radioecological Sensitivity of a certain area[1]

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The Concerted Action *Vulnerability Forum*, sponsored by the Commission of the European Communities, aims at the introduction of a new physical quantity that will reflect the Vulnerability or Radioecological Sensitivity of a more or less geographically homogeneous area in the case of a nuclear accident. This physical quantity could be the basis for a scale, akin to the Richter scale in seismology, that could be used for the characterisation of the area with respect to expected detriment from such an accident. This report summarises preliminary results on the subject of quantification of *Radioecological sensitivity*, as they have emerged from three Consultation Group Meetings of the Radioecological Sensitivity Forum during the past two years.

1 The process of quantifying Radioecological Sensitivity

When a new physical quantity is defined in the natural sciences, this is done in terms of other previously defined quantities. We define, for instance, *Force* (F) in terms of *mass* (m) and *acceleration* (a) as $F = m \cdot a$. All physical quantities may be defined ultimately in terms of three basic physical quantities, usually taken as Mass (M), Length (L) and Time (T). Again taking *Force* as an example, we can express the physical dimensions of F as $\mathrm{F = M\,L\,T^{-2}}$. This property of nature (which has nothing to do with the three dimensions of space) is not entirely understood today. Thus, if we are to quantify *Radioecological sensitivity* (S) we should do so in terms of well-defined physical quantities and aim ultimately to write down a formula [S = ...]. This formula will also furnish the units in which S will be measured.

As pointed out during several Discussion Meetings of the experts involved in this endeavour, before proceeding with quantification, certain aspects of the notion of *Radioecological sensitivity* must be decided. These are summarised below.

<u>End-Point Considerations</u>

Intuitively, *Radioecological sensitivity* has to do with the detriment, injury or ill effects induced by an event. It was decided from the start that the focus for evaluating such a detriment should be man. Thus, qualitatively, *Radioecological sensitivity* may be defined as *the expected ultimate detriment to man from a given radioecological disturbance*. Given this definition, one has to decide which already defined physical quantity best expresses the notion of *detriment.*

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Integral Versus Specific Quantities

In an attempt to describe quantitatively a certain physical phenomenon one often finds it necessary to define more than one physical quantities. In this context, we may distinguish two categories of physical quantities: *Integral* and *Specific*. Integral quantities focus on a given object or state as a whole whereas specific quantities refer to intrinsic properties of the object or state, devoid of "geometry" and allow comparisons. Examples of these categories are furnished by the pairs *mass - density*, *resistance - resistivity* and *force - pressure*. Of course, the quantities within each pair are connected through the geometry of the object. Thus, we may write the density (d) in terms of the mass (m) of an object as

$$d = \frac{m}{V}$$

in which V is the volume, or for a wire of length L and cross section A

$$R = \rho \frac{L}{A}$$

in which R is the resistance and ρ the resistivity.

It is quite possible that the quantification of *Radioecological sensitivity* will lead to the definition of both integral and specific quantities.

2. A scenario for the quantification of Radioecological Sensitivity

Let us consider a region of area A (m^2) which receives a total deposition P (Bq) of some radionuclide I (^{137}Cs, ^{90}Sr, etc.). According to a scenario that has been proposed, we may consider as the detriment to a man living in this region the effective dose that he will receive from this deposition until he or she reaches a predefined age T_0 (e.g. T_0 = 70 y). This scenario is explored in some detail below.

Specific Radioecological Sensitivity

The effective dose that an individual receives over a period of time, until he or she reaches the age of T_0 years, depends both on the isotope I that causes the dose and the age of the individual T at the time of onset of the deposition. Subtracting all factors of geometry (the area of the region, the intensity of the deposition and the composition of the population) we may define a basic specific physical quantity, which we may call *Partial Radioecological sensitivity* $S_I(T)$ as

The effective dose, accumulated by an individual of age T at the time of the incident until he or she reaches the age T_0, if the deposition of isotope I in the region is 1 Bq m^{-2}.

If one accepts this definition, then the concept of *Radioecological sensitivity* of a region is best represented by the average effect of the exposure to the deposition of all ages represented in the population. Thus, one can define the *Radioecological sensitivity of a region to isotope I* as

$$S_I = \int_0^{T_0} S_I(T) f(T) dT \tag{1}$$

in which $f(T)$ is the age distribution function of the population, normalised to unity, i.e.

$$\int_0^{T_0} f(T) dT = 1. \tag{2}$$

For a mixture of isotopes in the deposition one can go one step further and define a quantity that describes the Radioecological sensitivity of a region with a single number. If a_I is the fractional population of isotope I in the deposition, one can introduce the quantity

$$S = \sum_I a_I S_I \tag{3}$$

with the condition, for normalisation purposes,

$$\sum_I a_I = 1. \tag{4}$$

All physical quantities introduced above as some form of '*Radioecological sensitivity*' are measured in Sv Bq^{-1} m^2.

Integral Quantities

The integral physical quantity that emerges naturally in this scenario is what may be termed the *Expected Detriment* (due to a specific isotope *I*) D_I. Again, intuitively, the *Expected Detriment* to a region should be:

- proportional to the Radioecological sensitivity S_I of the region

- proportional to the deposition P_I of isotope I in the region
- proportional to the population N affected
- inversely proportional to the area A of the affected region.

Folding in the geometry of the region we may thus write

$$D_I = \frac{PNS_I}{A} = pNS_I \tag{5}$$

where in the last step of eqn (5) we have used the specific deposition p (Bq m^{-2}) in the region

$$p = \frac{P}{A}. \tag{6}$$

Finally, following the practice reflected in eqn (3) one can define the *Detriment* to a region due to all isotopes in the deposition, expressed with a single number, through the relation

$$D = \sum_I a_I D_I \tag{7}$$

under the normalisation condition of eqn (4). The units of the *Expected Detriment D_I* and the *Expected (Grand?, Total?) Detriment D* are man Sv.

Calculation of Radioecological sensitivity

The quantity that needs to be calculated first according to the above scenario is the *Partial Radioecological sensitivity $S_I(T)$*. Such a calculation may be described with the schematic contained in Fig. 1. The steps in the calculation proposed by this scheme are as follows:

1. The dietary habits of the population in the region are determined and food products of primary importance in the diet (e.g. milk, meat, wheat) are identified. A 'model diet' for the region is determined in the form of a set of coefficients $\{b_m\}$, each of which represents the daily, monthly or yearly intake of food product m (e.g., in kg d^{-1}).

2. By definition, the aggregate transfer coefficients $T_{ag}(I,m)$ for the transfer of isotope I to food product m in the model diet is the contamination concentration in the product resulting from a deposition of 1 Bq m^{-2}. Numerical values of T_{ag}'s will depend primarily on soil type, agricultural practices, weather conditions,

etc. and may be estimated from values measured in regions with similar characteristics. Thus the total activity intake $R(I)$ of an individual in the region, resulting from a deposition of 1 Bq m^{-2} of isotope I, will be given by

$$R(I) = \sum_{m} T_{ag}(I,m)\, b_m \qquad (8)$$

where the sum extends over all items in the model diet.

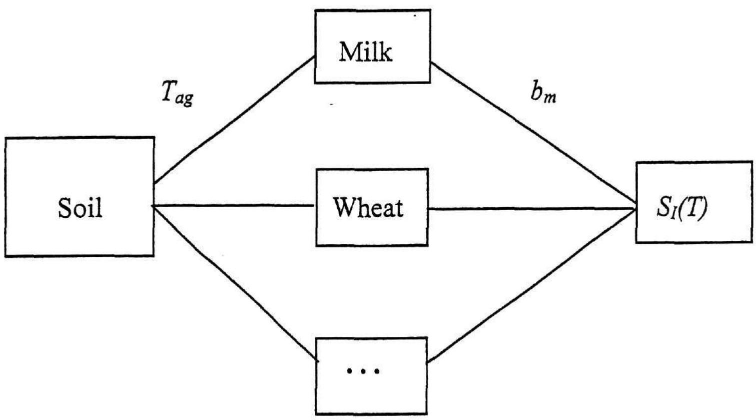

Figure 1. Successive steps in the calculation of Partial Radioecological Sensitivity S_I(T).

3. Given the daily intake $R(I)$, the Partial Radioecological sensitivity $S_I(T)$ may be calculated according to the method prescribed in ICRP Publication 30.

Following this calculation, one could proceed to calculate the quantity in eqn (1), which further requires knowledge of the age distribution function $f(T)$. It is noted that the shape of $f(T)$ will significantly affect the radioecological sensitivity of a region. Since activity intake is expected to affect younger age-groups to a much greater degree, a skewed age distribution curve, such as the one, for instance, encountered at remote rural areas (only old people in the villages) will result in a lower numerical value of S_I.

The Radioecological Sensitivity scale

The quantity defined in eqn (3) can be evaluated in order to express Radioecological sensitivity through a single number and thus create, for purposes of comparison, a *Radioecological sensitivity Scale*, such as the Richter scale in seismology. To do this, one needs the coefficients a_l in eqns (3) and (4). These may be taken from the double-humped nuclear fission curve or could be calculated in the framework of some climatic model, which predicts the composition of the expected fallout in a region from a possible nearby or distant source. The latter, however, should be a formidable job!

Epilogue

An attempt has been made in this report to present one of the possible scenarios for quantifying the notion of *Radioecological sensitivity*. Needless to say, there are several alternate routes one can follow. The various scenarios will depend primarily on the physical quantity, or combination of physical quantities, chosen to represent *Radioecological sensitivity*. For instance, one scenario considered is to use fluxes of radioactivity emanating form a given area through foodstuffs. It is possible that a set of T_{ag}'s for the region could also do the job equally well. All these possibilities will be explored and worked out in some detail in the remaining period of the Concerted Action underway.