ALARA- AND DE MINIMIS CONCEPTS IN RADIATION PROTECTION AND THEIR APPLICATION FOR THE NATURAL RADIATION ENVIRONMENT

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ABSTRACT

Normal levels of the natural radiation environment (NRE) are excluded from the dose equivalent limitation system, although they cause the largest contribution to the radiation burden of man. The significance from the different radon sources of the NRE and technical modifications of the NRE exposure are discussed with respect to their overall significance to the problem of applying the ICRP-ALARA-principle to man's exposure to the NRE. As an alternative graded de minimis-levels within a unified concept of radiation protection are proposed as a regulatory cut-off policy for "negligible" levels of radiation dose.

NRE AND TENR LEVELS

The natural radiation environment (NRE) and sources of technologically enhanced natural radiation (TENR) represent the largest sources of exposure to ionizing radiation for the general public. Although even "normal" NRE exposure exceeds levels from artificial sources by far, this type of radiation exposure is not intended to be subject of any system of dose limitation (IC77). Practical radiation protection problems arise from the overlapping definition of "normal" and "technologically enhanced" NRE sources:

a) Recycled industrial wastes, e.g. phosphogypsum from fertilizer industry or fly-ash from coal power plants, are increasingly used as construction material. The high ^{226}Ra concentration of some of these materials, up to 1220 Bq/kg (US75), also results in an increased equilibrium equivalent concentration (EEC) of radon inside such dwellings, typically 260 Bq/m^3 (UN82).

b) Natural building materials, such as concrete based on alum shale, contain high ^{226}Ra-levels and represent a significant source for increased indoor radon daughter levels up to 770 Bq/m^3 (Sw83).

c) Efforts to reduce the energy consumption for heating purposes consist mainly in a general reduction of the ventilation rate. This can increase the indoor radon concentration in such energy-efficient buildings up to 1000 Bq/m^3 (Ne82).

Considerations about the mechanism of the effect of energy deposition at the cellular level prove the concept of a dose- or LET-threshold in radiobiology as logically invalid (Ka82). This is in agreement with the basic no-threshold-concept in the system of dose limitations adopted by the International Commission on Radiological Protection (ICRP). The logical consequence of this (admittedly cautious) approach is a unified concept of radiation protection, where <u>every</u> source of ionizing radiation is subject to control regardless of its origin, since the biological target "cell" cannot discriminate between energy deposition due to NRE, TENR or artificial radiation exposure. It appears particularly illogical to exclude voluntarily the most significant source of exposure of the general public, i.e. NRE, and to concentrate most efforts on artificial sources which deliver less than 2% of the total dose to the public (St83).

ALARA AND THE NRE

The objective of radiation protection should be primarily the protection of the individual against detrimental effects resulting from radiation regardless of source type. In the ICRP-system of dose limitation for artificial sources it is proposed that the limitation of stochastic effects is achieved by keeping all justifiable exposures as low as reasonably achievable (ALARA-principle). Two caveats are included, i.e. economic/societal factors have to be taken into account and the dose-equivalent limits shall not be exceeded (IC77). Risks from NRE can only be subject of regulation, if the sources can be controlled. However, it has to be considered that NRE-source control is not only dependent on the development of technical measures to control NRE exposure, but also on the public acceptance of risk and the willingness to invest in NRE-risk control. A decisive factor are the financial resources available for reduction of <u>all</u> environmental risks, of which "radiation" represents just one aspect.

In order to demonstrate the application of the ALARA-principle a "worst-case" has been assumed: average radon (Rn) EEC value indoors of 230 Bq/m³, i.e. 15 times above normal levels. Such levels can be found in dwellings built predominantely of materials with elevated radium content. The annual effective dose equivalent amounts to about 15 mSv for inhabitants of such houses. Technical remedial actions range from the application of wall-sealants to exchange of the subsoil with costs up to US $ 10 000 per dwelling. In Fig. 1 the standardized societal and protection costs are compared for this model dwelling. Assuming a total removal of the radon pollution down to "normal" levels of about 1 mSv by using soil replacement techniques, protection costs (X) increase non-linearly. Societal costs (Y) increase linear, assuming linear dose-response relationships and a no-threshold lung cancer risk.

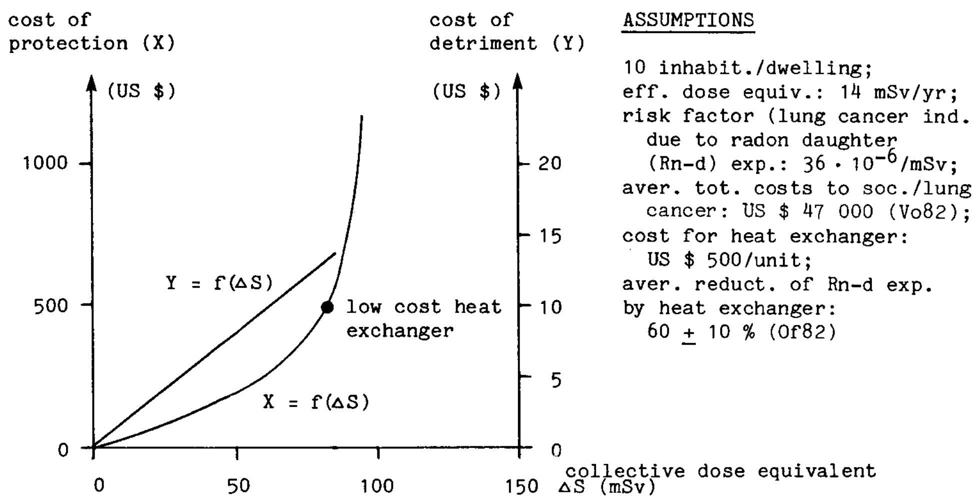

Fig. 1 Comparison of costs for technical remedial action against elevated radon daughter exposure and costs to society due to induced lung cancer cases, standardized for model dwelling

(figures rounded to indicate degree of uncertainty)

ALARA-optimization condition is fulfilled at a value S* under the following conditions:

$$\underbrace{(\Delta X/\Delta S)_{S*}}_{A} = \underbrace{-(\Delta Y/\Delta S)_{S*}}_{B}$$

It can be seen that even for a low-priced remedial action (heat exchanger) the above equation is not fulfilled ($A \gg B$), i.e. application of the ALARA principle cannot be justified even for low-cost remedial actions at any NRE-exposure level.

DE MINIMIS AND NRE

From radiological studies it is known that deposition of energy from ionizing radiation at the cellular level results in the sterilization of a small proportion of the total cells, but also in the induction of various processes of repair and repopulation. The latter increases the threshold level of dose when irradiation is given over a long period (UN82). Therefore also NRE-exposure, which has been part of man's evolution and occurs through the total life span of any individual, must induce a very effective repair for a given level of detriment otherwise the human race would have been extinct by now. It has even been argued that a certain level of radiation exposure may not only be harmless, but is essential for the well-being of man (Lu80). As there is no zero-NRE-exposure for anybody and only a finite amount of financial resources available for general risk control, it has been suggested to use a certain cut-off level for artificial radiation sources, ranging from 10 to 100 µSv. For a comprehensive review of the de-minimis concept see ref. (Da81). This concept has the advantage that available financial resources and health physics manpower are used at an optimum. For a given dose frequency distribution in a population (about 2 - 5% of the people receive a dose an order of magnitude higher than the mean dose (St83a, Ho83)), it is the high dose group which should receive the largest efforts for reduction of their dose. The disadvantage of this approach is the possibility that summation of several "insignificant exposures" can eventually cause an exposure in excess of recommended limits. However, the probability for this to occur is low, if the cut-off level is set low enough to allow for a large number of such exposures to be required before a significant health hazard is associated with it.

In case of its application to NRE exposure it is essential to establish statistically significant NRE-dose-histograms for different population groups in various geographical areas. From this information the range of natural background doses can be determined and fractions thereof be used as de minimis-levels.

Defining a system of graded hierarchy for different de minimis levels, e.g. a "level of triviality" and "level of no regulatory concern" (0.1%, resp. 1% of the value of the detriment due to the collective dose equivalent of the NRE-exposure), provides a wide safety margin against any unwanted excess doses due to multiple de minimis exposures. Fig. 2 demonstrates the practical application of this scheme for the exposure conditions in a typical industrialized country. The total value of the detriment due to NRE exposure exceeds that for occupational exposure by a factor of over 200. Application of graded de minimis-levels within the framework of a unified radiation protection concept would enable the deregulation of many areas of occupational exposure presently requiring radiation protection practices, without imposing any significant health hazard to the worker. It is likely that implementation of such a scheme would improve the collective exposure conditions of the total population, since additional financial resources and manpower would be available to reduce the dose for those groups of the population, who at present receive high exposures in the general public as well as during occupational exposure.

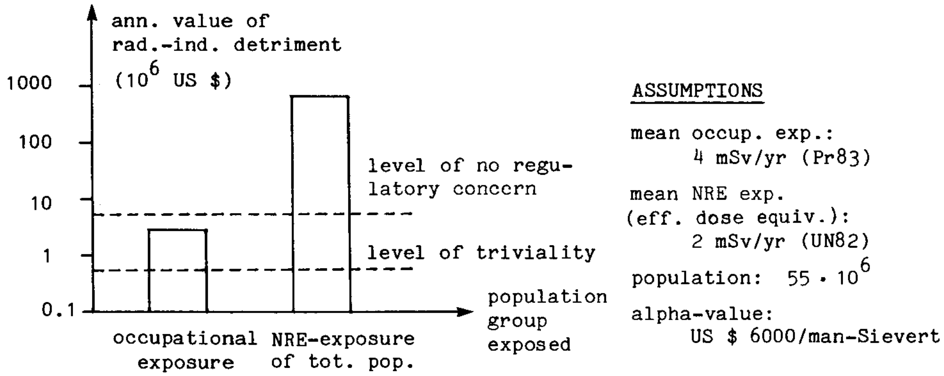

Fig. 2 Societal costs of detriment due to occupational and non-occupational radiation exposure in comparison to graded de minimis-levels

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