

**RC-9**

**Environmental surveillance programs and dose assessment.  
Characterization of individual members of the public**

**M. Lust**

ERPC, Tallinn, Estonia

# **Environmental surveillance programs and dose assessment. Characterization of individual members of the public**

M. Lust

ERPC, Kopli 76, Tallinn (Estonia), email: merle.lust@kiirguskeskus.ee

**Abstract.** Environmental surveillance programs give the information about the radioactivity levels in different spheres of the environment. However in order to estimate the compliance against regulatory limits, which are most commonly given as doses to public and due to the fact that the dose to the public cannot be measured directly and, in some cases, it cannot be measured at all, we need dose assessments. The paper will also give an overview of “representative person”, who is characterized as an individual (either hypothetical or specific) whose dose can be used for determining compliance with the relevant dose constraint.

This paper reviews and describes concepts and different methods for estimating annual doses based on recent international standards and give some examples about the possible mixtures of these techniques. Attention is given to the selection characteristics of the representative person, taking account three important factors: reasonableness, sustainability and homogeneity. The purpose of this paper is to attempt to provide some clarity on the characterization of the individual member of the public and some recommendations are outlined, aiming to contribute to the achievement of international harmonization.

## **1. Introduction**

The purpose of radiation protection system is to protect people and the environment against the detrimental effects of radiation exposure without unduly limiting the desirable human actions that may be associated with such exposure. Three fundamental principles have to be always taken into account: justification, optimisation of protection and application of dose limits. Dose values play important role in the radiation protection system, however in most cases doses to the public cannot be measured directly, or even they cannot be measured at all. This raises the need to use different methods to assess doses, based on calculations or measurement data from environmental surveillance programs, or on the mix of the both. In order to receive numerical result as a result of the dose assessment, there is need to characterise an individual, who can be either hypothetical or specific, whose dose can be used for determining compliance with the relevant dose constraint. ICRP Publication 103 [1] defines Representative Person, as an individual receiving a dose that is representative of the more highly exposed individuals in the population.

For a long time the concept of critical group was in use as basis for legislative recommendation and it was also the concept used in dose assessments. The concept was first introduced in ICRP Publication 7 [2] in order to have unified bases to evaluation compliance with the dose constraints. Defining of critical group is quite complicated, as there are several factors which had to be taken into account, for example: the location and age distribution of the potentially exposed group; dietary habits; special occupational habits; the type of the dwelling; domestic habits; hobbies and etc. This means that defined groups could be for example location or age-specific. The critical group may be based in the vicinity of the installations; it may include different sex and age groups, as adult males, adult females, pregnant woman, children, etc. In the process of defining the critical group it has to be kept in mind that this group would be representative of the more highly exposed individuals in the population [3]. Also it was important to follow the principles of the homogeneity and predictability with respect to radiation dose [4]. It is well known that the dose from a source received by any particular individual depends upon a number of factors, such as time, location, transport of radionuclides through the environment, and the characteristics of the individual. All these characteristics include physiological parameters, dietary information, residence data and any other individual specific information that is necessary to estimate annual dose. Taking into account all these factors listed above, it is clear that critical group concept was pretty difficult to implement, as a result there was a world-wide consensus about the need for a simple, but widely applicable, general system of protection. The term “representative person” is the equivalent of, and replaces, “average member of the critical group”.

## 2. Dose assessment

There are 3 types of exposure situations: normal, existing and emergency (Table 1). In case of normal (planned) exposure situation radiological protection can be planned in advance and also the magnitudes and extend of the exposures can be reasonably predicted. Emergency exposure situations are unexpected situations that may require urgent protective actions and in some cases also longer-term protective actions. Existing exposure situations are those that already exist when a decision on control has to be taken or at least they have to be considered.

Table 1. Examples of dose assessment in different exposure situations

<b>Situation</b>	<b>Prospective</b>	<b>Retrospective</b>
Normal	Determining compliance with the relevant dose constraint	Estimating dose to the public from past operations
Existing	Future prolonged exposures (e.g. after remediation)	Past exposures (e.g. occupancy of contaminated lands)
Emergency	Emergency planning	Actual impacts after emergency

In normal and existing situations, the dose constraint for the public is specified as an annual dose for regulatory and administrative purposes. Dose constraint can be defined as a level of dose above which it is unlikely that protection is optimised for a given source of exposure, and based on that action must almost always be taken. For determining exposures in an existing situation, it may be possible to use measurement data and other data that are specific to the location. These site specific data may reduce the uncertainties in estimated doses significantly. However most probably in the case of retrospective dose assessment for public exposure, the result will be a possible distribution of doses.

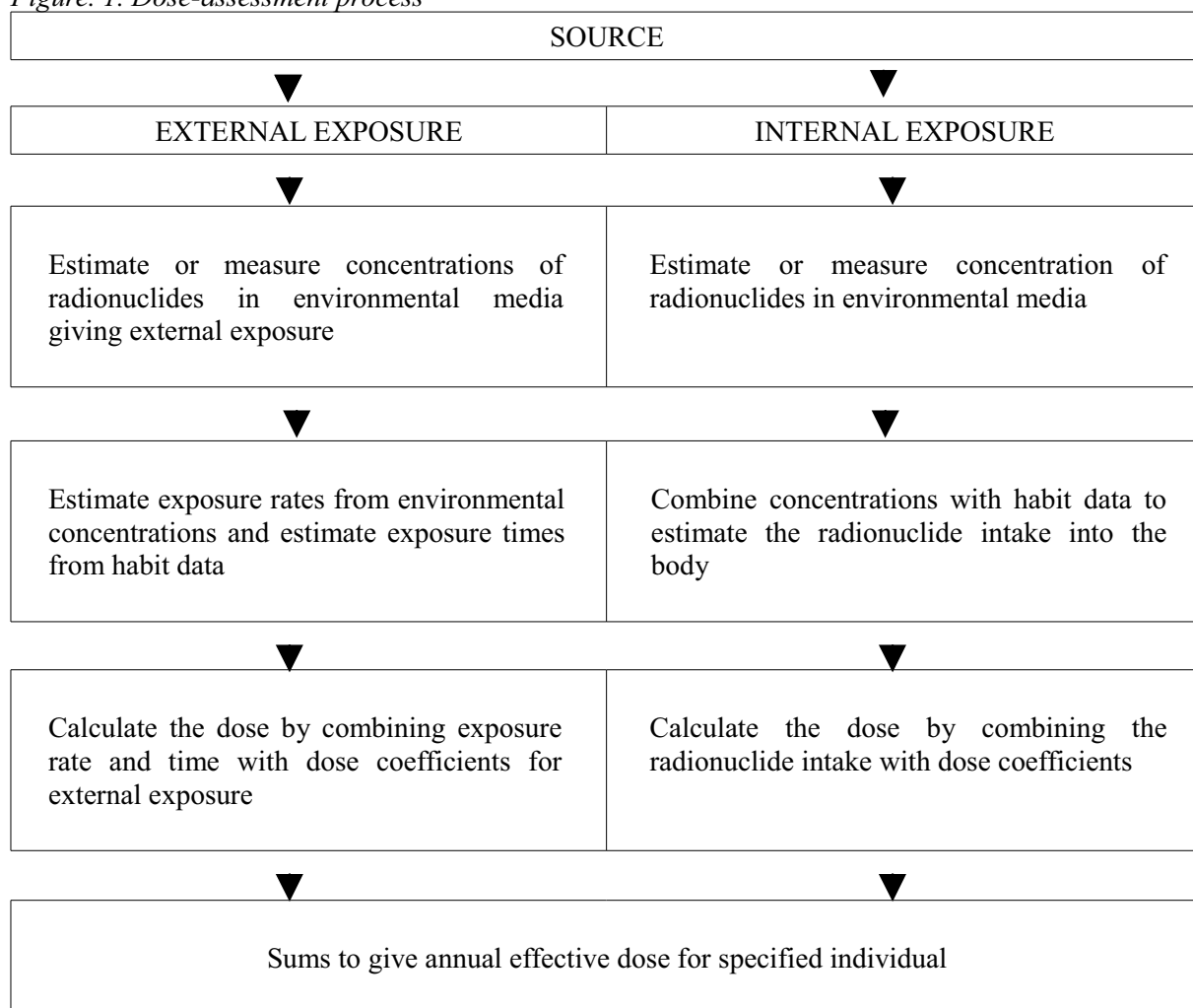
The assessment can be prospective or retrospective. Prospective doses are estimated for individuals whose exposure has not yet occurred, while retrospective doses are generally estimated for groups of individuals that are known to have received exposures. In assessing prospective exposures, individuals are assumed to exist who possess certain habit characteristics, whether or not those characteristics can be related to specific people.

Dose assessment and its preparation is a multi-stage process (Fig. 1):

1. Obtaining information about the source, including data on the types and quantities of radionuclides and radiations emitted;
2. Obtaining information about the environment, specifically the concentrations of radionuclides in the environmental media arising from the source in question. For doses due to external exposures either the concentrations in air, soil, or water, or the external dose rates are needed. For internal exposures it is necessary to know concentrations in food, water, or air that may be taken into the body. This part of the dose assessment is very tightly connected to environmental surveillance programmes;
3. Combining concentrations with habit data that are selected based on exposure scenarios of the relevant person or group. For external exposures, the amount of time spent in different radiation fields is needed, while in internal exposures the amount of food and water consumed or air breathed is required to estimate activity intakes;
4. Using of coefficients that either relate concentrations in air or soil to external dose rates (external doses), or that convert a unit of intake into dose (internal doses). Dose coefficients are estimated using models of radionuclide behaviour and radiation absorption in the body, and have been derived and published by ICRP.
5. Summing the contributions from external and internal dose as appropriate. It is important to recognise that dose assessment is an iterative process.

The purpose of doing the assessment will usually define the type of assessment to be conducted, and the degree to which specific information is incorporated. Depending from the circumstances, the type of the assessment may vary, for example planning, optimisation, and compliance will require different types of assessment. Planning and optimisation usually consider a variety of exposure circumstances and evaluate where there are opportunities for further protective measures. Compliance assessments, in contrast, are usually designed to demonstrate specifically that predetermined condition either are, or are not, being met. The methods used for estimating annual doses range from deterministic calculations to more complex probabilistic techniques. In addition, a mixture of these techniques may be applied.

Figure. 1. Dose-assessment process



Dose assessment needs specific data input, especially in the first three stages. The following are just some examples:

- First stage: in cases of discharges to the environment – discharges for radionuclides of interest, stack heights, proximities of relevant neighbouring buildings, physical and chemical forms of the material, and meteorological conditions. Direct external exposure from sources through shielding, or via scattering or refraction by material in the atmosphere should also be examined.
- Second stage: environmental concentrations at various locations are obtained by the measurements (may be as part of environmental surveillance programme), by modelling the dispersion and transport of radionuclides through environmental media or by a combination of both. Both measurements and modelling will have associated uncertainties.

- Third stage: combination of concentrations of radionuclides with habit data and other information defined by exposure scenarios. Has to consider: location, diet, lifestyle activities leading to radiation exposure and age-dependent physiological factors such as age and breathing rates. Often this data can be obtained from available information about local population, however not always it is the case.

Prospective assessments are to estimate future exposures and to show whether a proposed course of action is acceptable and optimised. These assessments have to make assumptions about the future conditions. They are also used to indicate if a continuing situation will comply with the relevant dose constraint for future years. Assessments may incorporate more detailed information about present site-specific conditions. In case of the emergency situations the prospective assessments are conducted if radioactive materials are released to the environment and the public may be exposed. The assessment would use available field data and measurements to estimate doses in order to provide recommendations for short-term protective actions. They can also be used in the late phases of the emergencies, when the event is under control and the protective actions have been implemented, as any remaining residual radioactivity is essentially one of continuing exposure and becomes as part of existing exposure.

In a probabilistic assessment of dose, whether from a planned facility or an existing situation it is recommended that the representative person should be defined such that the probability is less than about 5% that a person drawn at random from the population will receive a greater dose. Attention should also be given to the region and accompanying population where the assessment is being conducted to define the representative person. The simplest deterministic method for the assessment of compliance is a screening evaluation. This method typically makes use of simplifying assumptions that lead to a very conservative estimate of dose based for example, concentrations of radionuclides at the point of discharge from the source. Another simplifying assumption is to consider a single age group. If the results of relatively conservative screening assessments demonstrate that doses are well below the relevant dose constraint, there may be no need for the further detailed assessment of dose.

Additionally to the mentioned cases, there might be situations in which the exposure is not certain to occur and the attributed dose may only have a small probability of occurring, these are called potential exposure. Potential exposure should be evaluated on the basis of the combination of the probabilities that radiation dose will be incurred and the probability of harm given that the dose has occurred. The identification of the representative person in potential exposure situations should take into account the probability of exposure in addition to the other factors in the assessments. In addition to characterising the habits, locations and environmental concentrations of radionuclides, it is necessary to characterise the probability that the individual is exposed.

### **3. The representative person**

The source and the exposed individual are fundamental elements in each category of the exposure, whether occupational, medical or public. There must be a clear understanding and characterisation of the individual for whom the dose is being assessed. Calculated doses can then be compared with the dose constraints [6]. The representative person is the hypothetical individual, who receives a dose of representative of the more highly exposed individuals in the population. The representative person is equivalent to, and replaces the average member of the critical group.

In selecting characteristics of the representative person, three important concepts should be borne in mind: reasonableness, sustainability and homogeneity. Doses to the public are prospective (may occur in the future) or retrospective (occurred in the past). Prospective doses are for hypothetical individuals who may or may not exist in the future, while retrospective doses are generally calculated for specific individuals.

In considering dose to the representative person, a number of factors should be taken into account:

- the dose assessment must address all relevant pathways of exposure;
- the dose assessment must consider spatial distribution of radionuclides to ensure that the individuals receiving the higher exposures are included in the assessment;
- habit data should be based on the population exposed and must be reasonable, sustainable and homogeneous;
- appropriate dose coefficients have to be applied to specific age categories.

It is important to include appropriate contributions from all models of exposure. However in some cases it is possible that one pathway or a mix of few pathways determine the exposure. Assumptions can be made so that only the pathways that contribute significantly to the exposure are taken into account. For the time period of about 50 years into the future it is reasonable to assume that characteristics of individuals can be based on current habit data. In assessing dose in prospective situations it may be appropriate to recognize that institutional controls on land use could be in effect. Climatic conditions may also change and influence the doses. For example the possibility of future changes in land use may need to be considered in a prospective assessment. Currently there may be no agricultural production in the vicinity of a proposed facility, but such production could start during the facility's proposed lifetime due to the climatic changes.

Characteristics are described by age-dependent physiological parameters and habit data that include dietary information, residence data, use of local resources, and any other information that is necessary to estimate dose. It is important that individual habits used in the deterministic approach are average habits of a small number of individuals who are representative of those more highly exposed, and not the extreme habits of a single member of the population. The distribution of habits should be appropriate for the location or situation under consideration. For example, the discharges to a coastal environment are the subject of an assessment; the distributions of habits should at least reflect the behaviours of residents of coastal communities. If specific habit data for a local population are not available, values may be derived from appropriate national or regional population data. Reasonableness implies that the habit data apply realistically to an individual and are not outside the range of that what people encounter in day-to-day life, it has to be kept in mind using probabilistic or deterministic methods. Homogeneity addresses the degree to which extremes in particular habit data are, or are not, included in the assessment. Necessary degree of homogeneity in habit data in the highest exposed group depends on the magnitude of the mean dose in the group as a fraction of the relevant dose limit or constraint. The sustainability addresses the degree to which the selected habits can be continued over the time frame of the assessment. Habit data need to be sustainable. For example, the total dietary intake should be consistent with credible calorific requirements or to think that the same individual receives daily nutrient requirements independently from each other (agriculture and fishing). Also it is inappropriate to assume that all foods consumed in an area are grown within that area if it is apparent that the location and the land area available could not support the assumed dietary intake. Care should be taken to avoid selecting extreme values for variables to prevent overestimation.

#### **4. Uncertainties of dose assessment and age-specific dose coefficients**

Variability and uncertainty are inherent in any process of defining individual characteristics and in estimating doses. Variability refers to real and identifiable heterogeneity or diversity in nature. Uncertainty arises from unavoidable limitations in the assessment. Whether dose are estimated by using measurement data, by applying models or through a combination of measurements and calculations, the variability and uncertainty contribute to a distribution of possible values. Taking account different data sets needed in the process of the dose assessment, it is easy to conclude that there are several uncertainties connected. As bases the sources of variability can be classified into three categories: spatial variability, temporal variability and interindividual variability [7].

Some quantities have values that are measured or estimated as part of the assessment, and quantities that have values that are selected either by the ICRP or by other organisations. For example dose constraints, weighting factors and dose coefficients, when used in the process of assessing compliance and in decision making, are selected as fixed point values and are assumed not to be uncertain. Of course these values have uncertainties as well; however these have been taken into account in establishing selected values of quantities. Final decision about how to include uncertainties in the estimation of dose for compliance purposes should be made by the regulatory authority.

Dose coefficients are important factor in the dose assessment. There is dose variability per unit of exposure with age and ICRP has issued age-specific dose coefficients [8, 9], which allow the calculation of dose for members of public in six age ranges covering the time period from infancy to 70 years of age [10, 11]. There are also dose coefficients for the embryo/foetus for radionuclide intake by the mother and dose coefficients for the newborn child for radionuclides in the mother's milk. Six age categories were used for a long time, however in order to simplify the assessments, it is now recommended by ICPR [5] to use only three age categories for estimating annual dose to the representative person in case of for prospective assessments. Use of the smaller number of the age groups can be justified also based on several factors. For example most facilities are expected to operate for a period of at least 50 years. This means that the same person is exposed for a long period of time, over number of years. In other words, the concept of continuing exposure to the same individual justifies the use of a limited number of age categories that cover several years of a person's life. Even for the case of the disposal of long-lived radioactive waste, where doses to the public may be incurred in the far future over the entire life of the individual, ICPR has stated that: it is then reasonable to calculate the annual dose/risk averaged over the lifetime of the individuals, which means that it is not necessary to calculate doses to different age groups, this average can be adequately represented by the annual dose/risk to an adult.

ICRP dose coefficients give the committed dose from intake in a single year. This conservative approach ensures that individuals are protected over a lifetime of exposure, regardless of the number of the years for which are exposed. For example in case of actinides, dose coefficients take into account the integrated commitment for a lifetime of exposure, which overestimates dose to an individual in any given year. ICPR allows averaging over a 5-year period in the evaluation of compliance with the dose constraint [4]. With the exception of actinides; the differences among dose to different age groups are generally small in comparison with uncertainties typically found in the assessment of dose to the public. This is why it is recommended that the annual doses for the representative person should be defined by three age categories, which are: 0-5 years (infant), 6-15 years (child) and 16-70 years (adult). For practical implementation of the recommendations, please have a look to the Table 2. The shorter time period is selected for the infant age category, when dosimetric characteristics are changing most rapidly. Use of these 3 groups is sufficient to characterise the radiological impact of a sources and to ensure consideration of younger, more sensitive populations.

*Table 2. Dose coefficients recommended for determining compliance with the dose constraint*

<b>Age category (years)</b>	<b>Name of age category</b>	<b>Dose coefficient and habit data to be used</b>
0-5	Infant	1 year old
6-15	Child	10 year old
16-70	Adult	Adult

## 5. Summary

The result of the dose assessment has to be used to determine compliance. In case of using deterministic method assessment, the result is single value, which can be compared with the relevant constraint to determine compliance. The radiological protection is optimized when the dose to the representative person is less than the dose constraint. In case of using some probabilistic assessments of dose, it is possible that essentially all doses on the distribution will be predicted to be less than the relevant dose constraint. This means that compliance is readily demonstrated. If the estimated doses are above the dose constraint, they should be evaluated on a case-by-case basis. Summary of the dose-assessment methods is given in Table 3.

Table 3. Summary of methods used for determining dose to the representative person

	<b>Probabilistic</b>	<b>Deterministic</b>
Environmental concentration data	Distribution of estimated or measured concentration	Single values for parameters
Habit data	Range or fixed values for habit data	Average value for the more highly exposed group or 95 <sup>th</sup> percentile of appropriate
Dose coefficient	Fixed value based on age	Fixed value based on age
Dose to the representative person	Method selected by operator or regulator Representative person is identified such that the probability is less than about 5% that a person drawn at random from the population will receive a greater dose	Product of above values

In case of continuing normal situation, existing situation and emergency situations, monitoring radionuclide levels in the environment will normally be the most robust method for determining environmental concentrations of radionuclides. This means that monitoring programmes and dose assessments are inter-related, environmental surveillance programmes should be worked out guided by the identification of dominant pathways and radionuclides. In this process the detection limits and source of radionuclides have to be taken into account.

Calculation and assessments are getting more and more complicated as we have more powerful computers available for use. However in the process of selecting characteristics of the representative person (and also other variabilities), three important concepts should be borne in mind: reasonableness, sustainability and homogeneity. Stakeholders can be helpful in determining the reasonableness, sustainability, and homogeneity of habit data. Collaboration with stakeholders can significantly improve the quality, understanding and acceptability of characteristics of the representative person and also strengthen support for the process and the results.

## 6. References

1. ICRP, 2007, 2007 Recommendations of the International Commission on Radiological Protection. ICRP Publication 103.
2. ICRP, 1965, Principles of Environmental Monitoring Related to the Handling of Radioactive Materials. ICPR Publication 7.
3. ICRP, 1985, Principles of monitoring of radiation protection of the population, ICRP Publication 43.
4. ICRP, 1990, Recommendations of the International Commission on Radiological Protection.

- ICRP Publication 60, 1991.
5. ICRP, 2006, Assessing Dose of the Representative Person for the Purpose of Radiation Protection of the Public. ICRP Publication 101.
  6. ICRP, 2000, Radiation protection recommendations as applied to the disposal of long-lived solid radioactive waste, ICRP Publication 81.
  7. Tschurlovits, M., Taghizadegna, R., Engelbrecht, R. 2004. Handling Uncertainty and Variability in Risk Communication. Proc. IRPA 11, Madrid.
  8. Golikov, V., Balonov, M., Erkin, V., Jacob, P., 1999 Model validation for external doses due to environmental contaminations by the Chernobyl accident, *Health Physics* 77, 654-661
  9. Golikov, V., Balonov, M., Jacob, P., 2000. Model of external exposure of population living in the areas contaminated after the Chernobyl accident and its validation. Proc. IRPA 10.
  10. ICRP, 1996, Age-dependent doses to members of the public from intake of radionuclides. Part 2. ICRP Publication 67.
  11. ICRP, 1996, Age-dependent doses to members of the public from intake of radionuclides. Part 3. ICRP Publication 69.