2013 International Nuclear Atlantic Conference - INAC 2013
Recife, PE, Brazil, November 24-29, 2013
ASSOCIAÇÃO BRASILEIRA DE ENERGIA NUCLEAR - ABEN
ISBN: 978-85-99141-05-2

UTILIZATION OF CRITICAL GROUP AND REPRESENTATIVE PERSON METHODOLOGIES - DIFFERENCES AND DIFFICULTIES

Nelson L. D. Ferreira[1], Elaine R. R. Rochedo[2] and Bárbara P. Mazzilli[3]

[1] Centro Tecnológico da Marinha em São Paulo (CTMSP)
Av. Professor Lineu Prestes, 2648
05508-900 São Paulo, SP
nelson.luiz@ctmsp.mar.mil.br

[2] Instituto de Radiproteção e Dosimetria (IRD)
Av. Salvador Allende s/No.
22780-160 Rio de Janeiro, RJ
elainerochedo@gmail.com

[3] Instituto de Pesquisas Energéticas e Nucleares (IPEN)
Av. Prof. Lineu Prestes, 2242
05508-000 São Paulo, SP
mazzilli@ipen.br

ABSTRACT

In Brazil, the assessment of the environmental impact due to routine discharges of radionuclides, which is used to the public protection, normally is based on the determination of the so-called “critical group”. For the same purpose, the ICRP (2007) proposed the adoption of the “representative person”, defined as the individual receiving a dose representative of the members of the population who are subject to the higher exposures. In this work, are discussed, basically, the different characteristics of each one (critical group and representative person), related, mainly, to its methodologies and the necessary data demanded. Some difficulties to obtain site specific data, mainly habit data, as well as the way they are used, are discussed too. The critical group methodology uses, basically, average values, while the representative person methodology performs deterministic or probabilistic analysis using values obtained from distributions. As reference, it was considered the predicted effluents releases from Uranium Hexafluoride Production Plant (USEXA) and the effective doses calculated to the members of the previously defined critical group of Centro Experimental Aramar (CEA).

1. INTRODUCTION

In Brazil, the assessment of the environmental impact due to routine discharges of radionuclides, for the purpose of protection of the public, uses the concept of critical group, as defined by the National Commission for Nuclear Energy (National Nuclear Energy Commission - CNEN) in CNEN-NN-3.01 [1], which has the definition set initially by Publication 43 of the International Commission on Radiological Protection (ICRP) [2].

However, for the same purpose, the ICRP Publication 101 [3] proposed the adoption of the representative person, defined as the individual receiving a dose representative of the members of the population who are subject to the higher exposures. The term "representative person" is equivalent and replaces the “average member of the critical group” defined in previous publications of the ICRP.

Since the International Atomic Energy Agency (IAEA) included this concept in the new edition of the Basic Safety Standards [4], it seems very likely that the new recommendations of the ICRP will, at some point, be adopted in Brazil. Thus, it is necessary to assess the impact of this new methodology for facilities that have already established their principles of operation.

Currently, a study is being conducted for the assessment of radiological environmental impact in Brazil using the representative person methodology proposed by ICRP [1].

As part of the study, the effective doses are calculated to the previously defined members of the critical group of Centro Experimental ARAMAR (CEA) [5, 6, 7], considering the predicted potential releases of radionuclides from the Uranium Hexafluoride Production Plant (USEXA) to the environment.

As described in the references [5, 8], the critical group defined to CEA is hypothetical and is formed by members of the public who reside or may reside at a distance of 700 m from the release point, at the N (north) sector. A region of interest around the CEA site has been considered, which comprises the 10 km radius area centered in the meteorological tower (see Fig. 1).

In this work, the differences between the methodologies (critical group and representative person) are discussed, based on the data required for analysis and on the obtained results, on a preliminary basis. The difficulties encountered in the use of these methodologies are discussed too.

2. APPLICATION OF THE METHODOLOGIES - DIFFERENCES

2.1. Generic Aspects

In general, a radiological environmental impact assessment has the following steps [8]:

1) Characterization of the source, including the identification of the radioactive source term;

2) Simulation of the dispersion processes of the effluent in the receiving environment;

3) Establishment of habits of the local population;

4) Assessment of environmental transfers to determine the concentration of radionuclides expected in each compartment relevant to human exposure; and

5) Dose calculation and the consequent definition of the critical group and the operational parameters of the facility that will allow the control of public exposure, including the establishment of environmental monitoring program.

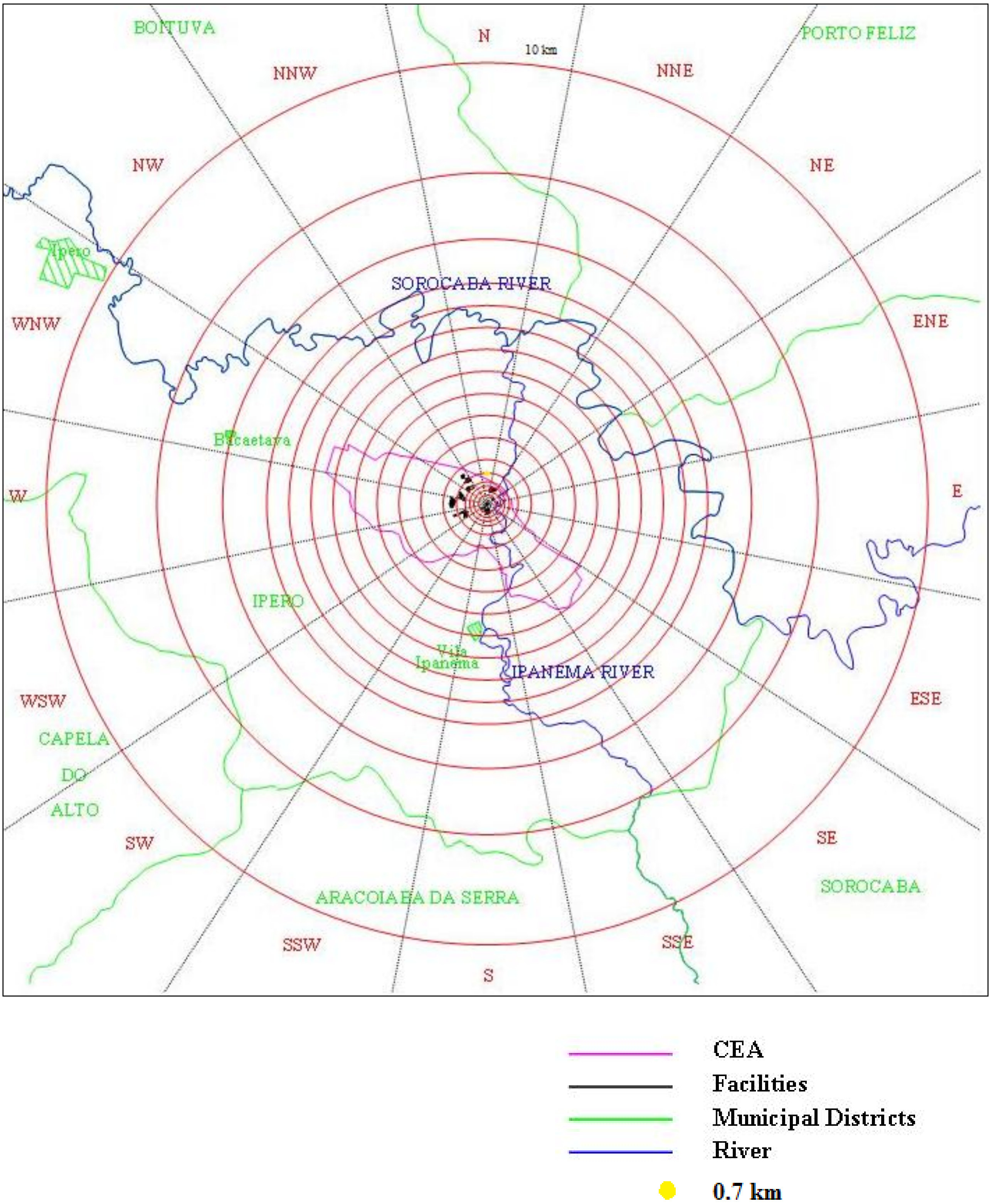

Figure 1. Overview of the region of interest around CEA

Historically, for the assessment of environmental radiological impact from routine releases, the IAEA recommends using simple, multiplicative models, considering that the expected changes shall not modify the environment equilibrium conditions.

In a generic way, to assess the annual effective doses, for both critical group and representative person, the methods recommended by the International Atomic Energy Agency [9, 10, 11] were used. Basically, the methodology comprises a mathematical model that describes the environmental transfer processes, known as compartments model. This model relates the amount of released radionuclide and effective dose received by individuals using environmental transfer parameters [5].

2.2. Critical Group

The following assumptions are adopted to define the critical group:

- All the exposure pathways should be considered;

- The group should be representative of the members of the population who receive the highest dose;

- The group should be relatively homogeneous with respect to age, diet and other aspects of behavior that affect the doses received;

- The critical group should not be confused with most exposed individuals; it should be a normal group of people rather than individuals associated with extreme habit's values; and

- The dose constraint should be evaluated in relation to the average critical group dose.

As mentioned before, the data used basically comprise source data (quantity, release frequency, etc.), site specific data (dispersion in the atmosphere and in water bodies, soil use, environmental transfer factors) and habit data of the local population.

In the selection of parameters used in the models, priority has been given to those related to the characteristics of the area. In their absence, regional or national data will be used, collected from the official organizations and from literature.

Some of the parameters used are radionuclide dependent as some may be age specific. In the case of the critical group of the CEA, only adults (> 17 years) has been considered.

To critical group dose calculations, average and conservative data values are typically used, and the result is expressed as a single value of dose.

2.3. Representative Person

ICRP [3] proposes that the dose to the public can be estimated deterministically and/or probabilistically.

- The analysis must account the contribution of all pathways of exposure (liquid and gaseous releases, direct external irradiation) from a source (facility);

- Extreme habits should be considered;

- The selected data related to habits should be sustainable, homogeneous, reasonable and compatible with the type of area and climate involved;

- The possibilities of future changes of use should be considered.

Data used to perform deterministic and probabilistic assessments, as proposed by ICRP [3], whenever is possible, must be used in the form of distribution of values.

To calculate the representative person dose by using the deterministic method, single values of parameters related to transport the radionuclide in the environment (eg, concentration) and average values and/or 95th percentile, when appropriate, to the so called habit data, can be used. By using this method, the result consists of a single value of dose.

For probabilistic assessment, data must be used, as much as possible, in the form of a probability distribution and the result is a distribution that presents a range of doses on their probability of occurrence.

In the ongoing study, doses are estimated for the following age groups: 1-2 years (more than 1 to 2 years), 7-12 years (more than 7 to 12 years old) and more than 17 years.

Based on the ICRP [3] and Jones and Smith [12], in the study are considered the following habit data:

<u>occupancy factors</u>: outdoor and exposures to air, water and shoreline
<u>type of housing</u>: shielding factor
<u>physiological parameters</u>: breathing rate
<u>Diet</u>: food consumption rate (vegetables, meat, poultry, egg, fish, milk)
fraction of the consumed food arising from the contaminated source.

The ICRP [3] recommends that "if more than one intake route for radionuclides provides a significant contribution to dose, it may not to be reasonable to assume that the 95th percentile habit data are applicable to all routes; the more dominant route should be assigned a 95th percentile intake, and a lower value should be assigned to other ways,…". Thus, in this study, for the scenarios that use distributions, the 95thpercentiles of habit data values are used just for the two routes of exposure that contributed most to the total effective dose. For the other items, average values are used.

In the ongoing study, effective doses to individuals located 700 m from the release point, the N sector, were estimated with the methodology of critical group and deterministic method for the representative person. The representative person probabilistic method was used to obtain the dose distribution resulting of estimated individual doses, calculated for an area of 5,000 m radius. The preliminary results are presented in Table 1.

Table 1: Effective annual doses estimated by different methods

METHOD	ANNUAL EFFECTIVE DOSE (Sv)		
	> 17 anos	**7 a 12 anos**	**1 a 2 anos**
Critical Group	**1.71E-06**	**1.66E-06**	**1.79E-06**
Representative Person - Deterministic	**2.61E-06**	**2.56E-06**	**3.27E-06**
Representative Person - Probabilistic			
average	**1.19×10^{-7}**		
95th percentile	**4.19×10^{-7}**		

Note:
1) The doses were estimated considering the exposure pathways identified as significant for the critical group of the CEA, as presented in [5, 6].
2) The discharge of gaseous and liquid effluents expected to be generated during normal operation of USEXA, as values presented in [8, 15], was considered.
3) The release of purefied non-enriched uranium and ^{232}Th (present only in liquid effluent) was considered.

Based on the results shown in Table 1, the use of probabilistic method for estimating individual doses in the area with 5,000 m radius in the region of interest, produced a result of a lognormal distribution, with the 95% percentile of 4.19×10^{-7} Sv per year. Considering that the reference value for the highest dose, estimated only for adults (> 17 years), it appears that this method produced dose results lower to those obtained with the deterministic method and that obtained for the critical group, by 16% and 25%, respectively.

A possible conclusion is that the probabilistic method does not lead to an excess of conservatism in the analysis as it leads to lower dose results than those obtained by other methods.

3. APPLICATION OF THE METHODOLOGIES - DIFFICULTIES

Based on the use of the critical group and the representative person methodologies, the main difficulties encountered are listed below.

1) The method of calculating dose for both group (critical group and representative person), although seemingly simple, requires the use of a large number of parameters, which creates difficulty in obtaining suitable values for the simulation of a particular

environmental situation. The use of representative person methodologies requires additional work to generate the distributions of the values of measured parameters.

2) When the values of environmental transfer factors appropriate to the types of climate and soil characteristics of the region of interest are not available, data from the international literature [12, 13, 14] were used, and it is appropriate to note that a significant portion of the data is not adequate to tropical countries, having been raised mostly in the United States and Europe, which produces unaccounted uncertainties on the estimates.

3) In Brazil, there is an inherent difficulty in absence of specific information for establishing critical groups such as, for example, the data available in the literature habits are limited to values suitable for adults. Furthermore, there are situations in which all the appropriate values are available unambiguously - it is customary to use conservative values of parameters, and so there is a guarantee that the doses obtained are not underestimated.

4) The methodologies for representative person proposed by the ICRP [3] require very comprehensive information, since they propose to use the distribution of values associated with the habit of all the individuals of all possible groups exposed rather than average habits of a group potentially more exposed.

5) In particular, the probabilistic analysis method for the evaluation of exposure of the public is not widely used in Brazil, and basic difficulties exist for its use, such as:

- Demand for computing resources not easily available;
- Survey of parameter values and establishing distribution curves appropriate when there are situations where even the estimate of an average value can include large uncertainties;
- Difficulty to prepare the database for simulation and interactions that should be allowed or prevented between parameter values and habits of the population, considering the diversity of uses and habits, particularly in relation to different age groups; and
- Difficulty in interpreting the results and the establishment of the representative person.

4. CONCLUSIONS

Regarding the difficulties encountered in the use of the methodologies for the control of public exposure, the main concern is related to the large demand of data to be collected, in addition to the need to derive distributions for both the deterministic and the probabilistic methods proposed for the representative person, besides that the probabilistic process is highly complex and demands for computational resources for performing probabilistic analysis.

Based on the results obtained, albeit in a preliminary way, it could be observed that the probabilistic method produced the lowest values of doses. Thus, it can be assumed that the use of parameters in the form of distributions, with the determination of a dose distribution, could be the most appropriate way to take into account safety without having to resort to very conservative assessments.

However, it can also be inferred that the use of the method for the critical group remains the best option to an efficient environmental impact assessment, as data is easier to be gathered and results are more conservative than those from a probabilistic assessment. With respect to the methods proposed by the ICRP [3] for representative person, the methodology of critical group is less complex than the probabilistic approach, and hopefully, produce less conservative results than the deterministic method for the representative person and so, it can be assumed that the critical group methodology possibly results in lower costs for safety purposes while complying with the level of safety for the public demanded by national and international regulations.

For future work, it is suggested to study the impact of the adoption of the representative person methodologies proposed by the ICRP [3] in the control of facilities that already have their operating principles defined based on the critical group methodology.

REFERENCES

1. Comissão Nacional de Energia Nuclear, *Diretrizes Básicas de Proteção Radiológica*, CNEN-NN-3.01:2011, Rio de Janeiro (2011).
2. International Commission on Radiological Protection, *Principles of Monitoring for the Radiation Protection of the Population*, ICRP Publication 43 (1985).
3. International Commission on Radiological Protection, *Assessing Dose of the Representative Person for the Purpose of Radiation Protection of the Public and The Optimization of Radiological Protection: Broadening the Process*, ICRP Publication 101 (2007).
4. International Atomic Energy Agency, *Radiation protection and safety of radiation sources: international basic safety standards - interim edition*, Safety Standards Series GSR Part 3 (Interim), Vienna (2011).
5. Ferreira, N. L. D., “Updated on Effluents Releases of the CEA Nuclear Fuel Cycle Facilities - 1995 to 2010 Period”, *2011 International Nuclear Atlantic Conference - INAC 2011*, Belo Horizonte, Brazil, October 24-28, 2011 (2011).
6. Ferreira, N. L. D. and Fonseca, L. P. S., “Characterization and Consequences from CEA Nuclear Fuel Cycle Facilities Effluents Releases - 1995 up to 2007 Period”, *2009 International Nuclear Atlantic Conference - INAC 2009*, Rio de Janeiro, Brazil, September 27 to October 2, 2009 (2009).
7. Ferreira, N. L. D.; Rodrigues Júnior, O. and Woiblet Júnior, P. F., “Determinação do grupo crítico para a INAP: uma avaliação preliminar”, *Congresso Geral de Energia Nuclear - CGEN 1996*, Rio de Janeiro, Brazil, October 27 to November 1, 1996 (1996).
8. Ferreira, N.L.D.; Rochedo, E.R.R. and Mazzilli, B.P., “Critical group vs. representative person: dose calculations due to predicted releases from USEXA” *Latin American IRPA Regional Congress on Radiation Protection and Safety - IRPA 2013*, Rio de Janeiro, Brazil, April 15-19, 2013 (2013).
9. International Atomic Energy Agency, *Generic Models for Use in Assessing the Impact of Discharges or Radioactive Substances to the Environment*, Safety Report Series 19, Vienna (2001).
10. International Atomic Energy Agency, *The Application of the Principles for Limiting Releases of Radioactive Effluentes in the Case of the Mining and Milling of Radioactive Ores*, Safety Series 90, Vienna (1989).

11. International Atomic Energy Agency, *Generic Models and Parameters for Assessing the Environmental Transfer of Radionuclides from Routine Releases: Exposure of Critical Groups*, Safety Series 57, Vienna (1982).
12. International Atomic Energy Agency, *Quantification of Radionuclide Transfer in Terrestrial and Freshwater Environments for Radiological Assessments*, IAEA-TECDOC-1616, Vienna (2009).
13. International Atomic Energy Agency, *Handbook of parameter values for the prediction of radionuclide transfer in terrestrial and freshwater environments*, Technical Reports Series 472, Vienna (2010).
14. Environmental Protection Agency, *Exposure factors handbook: 2009 update*, EPA/600/R-09/052A (2009).
15. Centro Tecnológico da Marinha em São Paulo, *Relatório Final de Análise de Segurança da USEXA*, rev. 0, São Paulo (2010).