Enhancing communication on Radiological Protection throughout Brazil

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Abstract. This paper focus on the potential value of Information and Communication Technologies (ICTs) to enhance communication on Radiological Protection throughout Brazil. The servers processing power added to the technology of relational databases allow to integrate information from different sources, enabling complex queries with reduced response time. It is our objective to provide radioactive facilities a complete repository for research, consultation and information on radiological protection in an integrated and efficient way. This web-based project works informatization of Radiological Protection Programs according to the positive tree published by AIEA in its Safety Series No. 102, the most generic and complete tree for an appropriate and effective radiation protection program. Up to this moment, the website counts on concepts, definitions and theory about optimization and monitoring procedures, interrelating information, currently scattered in various publications, in order to meet both Brazilian and international recommendations. The project involves not only the collection and interrelationship of existing information in the several publications, but also new approaches from some recommendations, such as potential exposures. Only few publications develop expressively the issue and, even though they provide fundamental theory, there is still lack of knowledge of failure probabilities, which currently constitutes a broad research field in radiological protection. This research proposes the development of fault trees and the analysis of different scenarios, suggesting paths to quantify probabilistically the occurrence of potential exposures, as well as probabilities to reach a certain level of dose. It is our target to complete the system in a near future, including other relevant issues, such as safe transport of radioactive materials, emergency response, radioactive waste management and decommissioning, among others. We believe the use of information technology for the radiological protection programs shall contribute greatly to provide information to Brazilian radioactive facilities throughout the country, spreading information to as many people as possible, minimizing geographic distances and stimulating communication and development.

KEYWORDS: radiological protection; ALARA; potential exposures; information and communication technologies.

1 INTRODUCTION

This paper focus on the potential value of Information and Communication Technologies (ICTs) to enhance communication and education on Radiological Protection Programs throughout Brazil. In order to establish a Radiation Protection Plan or a Radiation Emergency Plan, Brazilian facilities should take into account all procedures based on national and international guidelines and recommendations. This information can be found in several documents published by different organizations over the past decades: the International Commission on Radiological Protection (ICRP) [1], International Atomic Energy Agency (IAEA) [2] and Comissão Nacional de Energia Nuclear (CNEN) [3].

To meet national and international standards, the development of this research includes concepts, definitions and theory about radiological protection procedures in order to interrelate information, currently scattered in several publications and documents published in the last past decades. Radiological Protection Programs are developed according to the positive tree published by AIEA in its Safety Series No. 102 [4], which is considered the most generic and complete tree for an appropriate and effective radiation protection program.

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The main objective of this work is to provide Brazilian radioactive facilities a complete web-based repository for research, consultation and information. Moreover, this research involves not only the collection and interrelationship of existing information in the publications, but also further approaches from recommendations, comparing information, discussing present challenges and future possibilities towards protection and safety. This paper focus on Potential Exposure researches, which currently constitutes a broad research field in radiological protection.

2 METHODOLOGY

2.1 A web-based repository for radioactive facilities throughout Brazil

In Brazil facilities involving ionizing radiation are divided into nuclear and radioactive facilities. Nuclear installations cover the entire nuclear fuel cycle, which comprises nuclear materials mining, including power reactors and research, the production of radioisotopes for use in several human activities and also the reprocessing of fuel elements of nuclear reactors. Moreover, the radioactive facilities are those that make use of ionizing radiation in other peaceful applications of nuclear energy like in the industry, medicine, agriculture, environmental protection, among others. This division is due to the fact that the entire nuclear fuel cycle, including reactors, are government monopoly, while all other human activities involving ionizing radiation can be developed and used by the public under government supervision. Brazil is a large country with great distances between major cities and counts on hundreds of radioactive facilities located in different states. The project UNIPRORAD (Unification of Radiological Protection Programs) is a web-based tool to spread information and communication on radiological protection and safety for radioactive facilities all over the country [5].

The WEB platform tools and functionalities were developed according to target public needs, regarding new possibilities of media, like mobile access, feeds of content and information sharing. Moreover, taking into account this is a pioneer project with the prospect of long-term use, our challenge takes into account the development of a robust, effective, and flexible system, which can be easily adapted to future demands, this pioneer Project involves the combination of multiple computer technologies. That is a long term use Project that shell help greatly radioactive facilities and can be a reference for researchers in Portuguese spoken countries.

2.2 Delineation of the content

Regarding potential exposures, only few publications develop expressively the issue. The ICRP gives the first basic steps to develop potential exposures issues in Publication 60 [6]. In 1993, the same entity extends this work in its Publication 64 [7], focusing risks, probabilities, defense-in-depht and safety culture. In 1995, the International Nuclear Safety Advisory Group publishes INSAG-9 [8], a report on potential exposure in nuclear safety to complement IAEA's work on safety standards in the context of potential exposure. Discussing risks and probabilities and establishing policies for nuclear and radiation safety, this report repeats on its paragraph 34 the police also used by ICRP, literally transcribing the paragraphs about the justification of a practice, the optimization of protection and individual dose and risk limits. Later, in the same year, in December 1995, a report from CRPPH/CSNI/CNRA/RWMC Expert Group discussed the meaning and application of the concept of potential exposure [9]. This report of OECD/ NEA takes into account Publications ICRP 60, ICRP 64, AIEA SS114 and AIEA INSAG-9 [6] - [10]. According to this report, one of the principal issues considered is “an establishment of a common understanding and of agreed definitions concerning a number of terms used by the different communities sometimes with different meanings”. Therefore, this report brings further discussions of some terminologies, such as individual risk, safety, probability, frequency, event, sequence, scenario, consequence, limits and constraints, among others. Later on, the ICRP brings in its new publication about Potential Exposures, Publication ICRP 76 [11], in its section 62:

"The methods for optimization of radiation protection range from simple common sense to complex quantitative techniques (see Publications 37 and 55; ICRP 1983, 1989). Optimization of protection against potential exposure is still largely unresolved, particularly when probabilities are low and consequences are big (NEA / OECD, 1995). Although the present report conceptually equates risks from normal and potential exposures, simultaneous, formal optimization of protection against both types of exposure would be difficult. However, the use of devices for protection against potential exposures, as outlined here, already includes an element of optimization. Also, the reference risk used in this report corresponds to the risk associated with the highest occupational doses in an optimized operation, rather than to the risk associated with a dose at the occupational dose limit. Still, optimal protection against potential exposures is not necessary achieved at the same level of risk as optimal protection against normal exposures. This is because the costs of reducing risks from normal exposures may be quite different."

Although this publication recognizes that these two issues should be treated separately, it does not provide specific recommendations. Indeed, despite the NEA/ OECD report affirm that optimization of protection against potential exposure is still largely unresolved, it emphasises optimization, justification and individual dose and risk limits as principles aimed at reducing the probability of accidents [9]. Taking into account the above mentioned reports and publications, as well as Brazilian publications, the web- based system UNIPRORAD presents the criteria used for control of occupational exposures, discussing normal and potential exposures [5].

The content includes concepts, definitions and theory about the optimization programs, help decision making techniques, information related to protection costs, radiation doses and detriment. The project involves the creation of computerized models that comprise the various aspects of optimization:

- Concepts and definitions whose terminology will follow the definitions provided by the ICRP publications [12], [13] and IAEA [14].
- Structured models for optimization projects of radioactive facilities and models for the facility operation, according to guidance provided by ICRP [13].
- The three basic principles of radiological protection, namely: justification, optimization and dose limitation system, according to guidance provided by ICRP [12].
- Quantitative decision making techniques, according to the ICRP publications [12], [13] and some examples through interactive virtual components, so the user can quantify and sense the extent required in practical situations. These interactive components are original and have been exclusively created for this purpose.
- Estimates of the alpha value and the international and national examples according to the guidance provided by the IAEA [14] and the publication of the Commission of European Communities [15].
- The factors that could be quantified according to the guidance given by ICRP [13], which includes the methodology necessary to implement the optimization procedure for both the project and the operation of the radioactive facility.
- The construction of the optimization process, given its features, the stakeholders and the choice of the optimal options, which means the analytical solution, and the distribution of doses over time and space, inserting the matrix of collective dose to the decision making according to publication of the ICRP [16] and following the methodology suggested by it.
- The procedures for evaluation of exposure situations, and the basic guidelines, showing the actual dimensions of each situation [14] - [16].
- The principles and means of reducing exposure that will keep the actual dimensioning of each situation [14] - [16].
- The global components to be considered to define and implement an ALARA Program [14] - [16].

Furthermore, the content includes concepts, definitions and theory discussing monitoring procedures [17] - [20], such as authority and responsibility, classification of work areas, practical implications and engineering controls, operational procedures, reference levels, types of monitoring and its functions. The system provides detailed information about workplace monitoring and individual monitoring, discussing objectives, routine monitoring and task-related monitoring in each case. Workplace monitoring for air contamination, for example, cover the following topics: conventional and more convenient structure, reference level for air contamination, routine monitoring, task-related monitoring and interpretation of results. Also, it was created exclusively for this purpose, an interactive virtual component presenting hypothetical problem-based situations related to incorporation of radioactive materials by workers. Besides workplace monitoring for air contamination, there are detailed information about workplace monitoring for external radiation, workplace monitoring for surface contamination, individual monitoring for external exposure, individual monitoring for internal exposure and individual monitoring for skin and clothing contamination.

Regarding potential exposures, only few publications develop expressively the issue [7], [8], [11] and some recommendations are not developed, making it difficult to discuss information in a complete and clear way, even from the original publications. Therefore, this web-based project promotes the discussion of this subject, introducing potential exposures in more quantitative way than national and international recommendations. Articulating ICRP and AIEA valid recommendations and official reports, in addition to some scientific works published in major international congresses, the system suggests paths to help to quantify probabilistically the occurrence of potential exposures, as well as probabilities to reach a certain level of dose. For this purpose and further discussions, the system brings the table of range of probabilities given by publication ICRP 64 [7], as seen in Table 1, and discusses the annual occurrence probability of a potential exposure suggested by Sordi equations [21], as seen in Table 2.

Table 1: Range of probabilities in a year from which constraint may be selected

Sequence of events leading to doses treated as part of normal exposures	10^{-1} a 10^{-2}
Sequence of events leading to stochastic effects only but above dose limits	10^{-2} a 10^{-5}
Sequence of events leading to doses where some radiation effects are deterministic	10^{-5} a 10^{-6}
Sequence of events leading to doses where death is likely to result	$< 10^{-6}$

Source: ICRP 64 [7]

Table 2: Range of probabilities in a year from which constraint may be selected

Maximum admissible dose for risk limits	Maximum incident probability
100 mSv	1.0 x 10^{-2}
110 mSv	1.5 x 10^{-3}
120 mSv	8.0 x 10^{-4}
150 mSv	2.6 x 10^{-4}
200 mSv	1.0 x 10^{-4}
500 mSv	1.0 x 10^{-5}
1000 mSv	2.5 x 10^{-6}
2000 mSv	1.0 x 10^{-6}

Source: Sordi [21]

Another example of further discussions beyond the original publications are the development of fault trees, suggesting new possibilities, inspiring new attitudes towards protection and safety for professionals involved in radiological protection issues. There is still lack of knowledge of failure probabilities, which currently constitutes a broad research field in radiological protection. This research proposes complete and general scenarios constructions that could be extended and applied by similarity to any radioactive facility according to its specific situation. The scenarios proposed bring the interrelationship of 3 different publications:

- ICRP 76: using the following examples: fault tree analysis of the radiotherapy device, fault tree analysis of a modern irradiator and fault tree analysis of an accelerator for isotope production [11].
- AIEA 102: regarding the positive tree, published by in 1990, which is considered the most generic and complete tree for an appropriate program of radiation protection [4].
- AIEA TECDOC 430: bringing the requirements and symbols for the correct development of a fault tree [22].

3 FINAL CONSIDERATIONS

The web-based system UNIPRORAD proved to be a useful source of information. Google Analytics is used to investigate the website usage profile, collecting monthly reference data about visitors' profile. According to Analytics most recent monitoring reports, between 05/06/15 and 04/07/15, the website UNIPRORAD counted on 251 sessions of Brazilian visitors from 10 different states, among which 32.67% were new visitors. Results were similar to the following month, between 05/07/15 and 04/08/15, when the website received 267 sessions of Brazilian visitors from 16 different states, among which 24.72% visited the website for the first time. The percentage of visitors who return to web-based system UNIPRORAD indicates it has been an efficient tool.

Indeed, the system UNIPRORAD allows to face different publications comparing similarities, understanding differences or analyzing discrepancies among the several valid recommendations. This is particularly important to Brazilian Radioactive facilities, because in order to establish a Radiological Protection Plan or a Radiological Emergency Plan, Brazilian facilities should take into account all procedures based on both national and international standards, guidelines and recommendations. For example, IAEA and ICRP suggest different values for the investigation level for individual effective dose in monitoring procedures. The IAEA [2] recommends 6 $mSvy^{-1}$, which means 3/10 of maximum average annual limit. Nevertheless, the value of the investigation level suggested by the ICRP [1] is 1/10 of the maximum permissible annual limit, which means 5 $mSvy^{-1}$. In Brazil, according to CNEN, the level of investigation is 6 $mSvy^{-1}$. In this case, the question would be: "How to achieve compliance with ICRP and CNEN to define the investigation level of individual effective dose in the case of internal contamination monitoring?" In this case, recommendations (ICRP, IAEA and CNEN) are provided and answers are given to help understand these variations. According to CNEN the level of investigation is 6 $mSvy^{-1}$ / n where n is the number of sampling periods per year. The ICRP suggests 5 $mSvy^{-1}$ / n where n has the same meaning of CNEN rules and the investigation level is the recording level itself [1] - [3].

The content has been developed and structured to provide answers to all questions that should be reasonably asked to plan a Radiological Protection plan according to each user's specific situation. It is our target to complete the system in a near future, including other relevant issues, such as safe transport of radioactive materials, emergency response, radioactive waste management and decommissioning, among others. We believe that the potential of ICTs shall contribute greatly to provide information where it is needed, stimulating development in this large country where it is a strong challenge to ensure access to information to as many people as possible, minimizing costs and optimizing results.

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