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COMMUNICATION ABOUT OCCUPATIONAL EXPOSURE: LINKING WORKERS TO HIGH-QUALITY INFORMATION

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ABSTRACT

Brazil is the largest country of Latin America, with 8.5 million square kilometers divided into five regions with 3 time zones. In this large between-country distances, with plenty of radioactive facilities throughout the country, professional education and communication is a must and a challenge. This paper discusses a web-based project designed to provide effective communication about occupational exposure, linking geographically distant workers to high-quality reliable information. The web-based-project UNIPRORAD counts on concepts, definitions and theory about radiological protection based on both national and international standards, guidelines and recommendations. The content includes optimization, monitoring, potential exposure and communication on occupational risk agents in the workplace. Regarding potential exposures, it is essential to consider the concept of "risk" which, even among scientific community, seems to assume a great variety of meanings. Regarding risk agents in the workplace, it is necessary to discuss the identification and evaluation of the various risk agents (physical, chemical biological and ergonomic) addressing attention to their association to ionizing radiation. This article presents the authors' experience in the communication of radiological protection in Brazil, presenting global and specific issues on radiological protection, analyzing recommendations and discussing discrepancies among the several valid publications. It is our objective the dissemination of trustful updated communication, providing radioactive facilities relevant, accurate and understandable information. Finally, the article emphasizes the need to spread information wherever it is needed to inform as many people as possible, contributing to develop workers´ professional skills and to improve safety culture in workplace.

1. INTRODUCTION

Brazil is a federative republic formed by the union of 26 federal states, besides the Federal District. The country is divided into five regions (North, Northeast, Midwest, Southeast and South) with 3 time zones. It is the largest country of Latin America, with 8.5 million square kilometers and one of the world's most populous countries. In Brazil, facilities involving ionizing radiation are divided into nuclear and radioactive facilities. This division is due to the fact that nuclear facilities comprise the entire nuclear fuel cycle, power and research reactors, which are government monopoly. Radioactive facilities, on the other hand, can use and develop, under government supervision, other human activities involving ionizing radiation in other peaceful applications, such as industry, medicine, agriculture and environmental protection, among others. In Brazil, the national government entity, linked to the International

Atomic Energy Agency (IAEA) is the National Nuclear Energy Commission (CNEN)[1], which provides standards for radioactive facilities in the country. In June 2019 the official website of CNEN counted on 1867 licensed radioactive facilities. As an example, there are 626 facilities for industrial applications, among which 442 radioactive facilities for Nuclear Measurement Devices operating in 24 different states in the country[2] [1].

All radioactive facilities must establish a Radiological Protection Plan and a Radiological Emergency Plan in compliance with national and international requirements and recommendations. This information can be found in various documents published by different organizations over the past decades: International Commission on Radiological Protection (ICRP), International Atomic Energy Agency (IAEA) and National Nuclear Energy Commission in Brazil (CNEN). The IAEA and ICRP together have more than two thousand publications about safety and security. Many of them concern radiological protection; many of them completely superseded; many of them partially superseded; many of them published in English or Spanish; none of them published in Portuguese. The search for correct and complete information is a complex task for Brazilian workers. The great advance of the nuclear sector in the last past years imposes the need to constantly update the recommendations. In a rapid-changing world it is a must and a challenge to offer reliable updated information in Portuguese, to Brazilian radioactive facilities, operating in several states in this large-extension country.

Therefore, taking advantage of the potential value of Internet in modern Information Society and its institutions, our workgroup has created the web-based-system UNIPRORAD [2], designed to provide radioactive facilities high-quality reliable information, contributing to develop workers´ professional skills and to improve safety culture in workplace. This paper aims to present the important possibilities of Internet to spread information throughout Brazil, to as many people as possible, minimizing costs and optimizing results.

2. MEANS AND METHODS

In order to develop the WEB platform according to the needs of the target public, our work team has conducted an extensive research regarding the evolutions and trends of Information and Communication Technology (ICT) access throughout the country. To potentialize the effectiveness of this educational program, all data was essential, such as the proportion of companies using the internet, the proportion of employees who use computers or who have remote access to the system, the proportion of companies with network (LAN, intranet, extranet), activities with the corporate mobile technology, the proportion of employees with internet access at work, average download speed provided by the host service, type of activity performed by the companies using the internet, the proportion of companies with policies access restriction.

According to the Brazilian Internet Steering Committee (CGI.br), between years 2006 to 2008 there was a significant decrease in the use of the dial-up internet from 14% to only 5% [3]. Besides, there was significant progress regarding internal wireless network in corporations, that included only 14% of companies in 2005. Nevertheless, in 2009, 41% of Brazilian companies already claimed to have wireless network. These are only few examples that

[1] In Portuguese: Comissão Nacional de Energia Nuclear - CNEN

[2] Information collected in CNEN´s official website on 21th June 2019.

demonstrate the rapid evolution of events and the latest technological trends and advances of Information Technology [3].

In 2010, 97% of Brazilian companies with more than 10 employees used computers, and this percentage increased to 100% in the case of companies with more than 50 employees. The average percentage of employees, who used computers in the workplace, was equivalent to 45%. Among Brazilian companies that had a computer, 96% had Internet access, a percentage that reached 99% if one considers only companies with 50 or more employees [4]. Nevertheless, the proportion of employees who were able to use computers connected to the internet was only 38%. When each region was studied separately, access to internet were led by South and Southeast regions with a percentage of 40%, and the Midwest, which had the highest average rate with 43% of employees who used the Internet in workplace. Among the predominantly activities performed by employees in Brazilian companies, figured in third place the search for information and research activities [3-4]. In 2011, 13% of Brazilian companies claimed to have tablets, while in 2012 this percentage increased to 19%. In year 2012, 96% of Brazilian companies with computers declared to have local area network (LAN) infrastructure; 86% of these organizations had wired LAN, and 71% had wireless LAN. 40% of large companies claimed to use the 3G modem, which has been growing due to the trend towards laptops, tablets and mobile devices [4-5].

In 2012, mobile, desktop and laptop computers were already the main equipment of infrastructure access in Brazilian companies [6]. Therefore, one aspect evaluated in the survey was the maximum speed indicator for download most commonly hired by Brazilian companies. The most mentioned speed range was 1 Mbps to 10 Mbps, present in 48% of companies with Internet access. This represented an increase of 10 percentage points compared to 2011. Moreover, in 2010, the search for information and research activities in the workplace appeared in third place, activities carried out by 86% of Brazilian companies [4]. In 2012, the search for information and online services on the Internet was already in second place, among the activities predominantly performed by employees in Brazilian companies [6].

The project UNIPRORAD was implemented in 2012. Since then, these and other data should be periodically reviewed, so that the system will always be in accordance to the public needs. In recent years, there has been a noteworthy transformation in computer and smartphone use and their markets. First came tablets, which did not take off as initially expected, and, more recently, users have shifted to smartphones, as shown in Fig. 1. The official reports published in 2016 [7] bring new data about organizations that used corporate mobile phones by type of activities performed between years 2014 and 2015, mapping presence, activities, uses and quantity about corporate mobile phones and remote access. In addition to computers, considering smartphones in use in Brazil (190 million), which had surpassed computers in quantity (166 million), there were then 356 million devices (computers and smartphones together) to be in use in Brazil by the end of 2016. That represents 1.7 devices for every inhabitant, an impressive value and close to the per capita density of more developed countries.

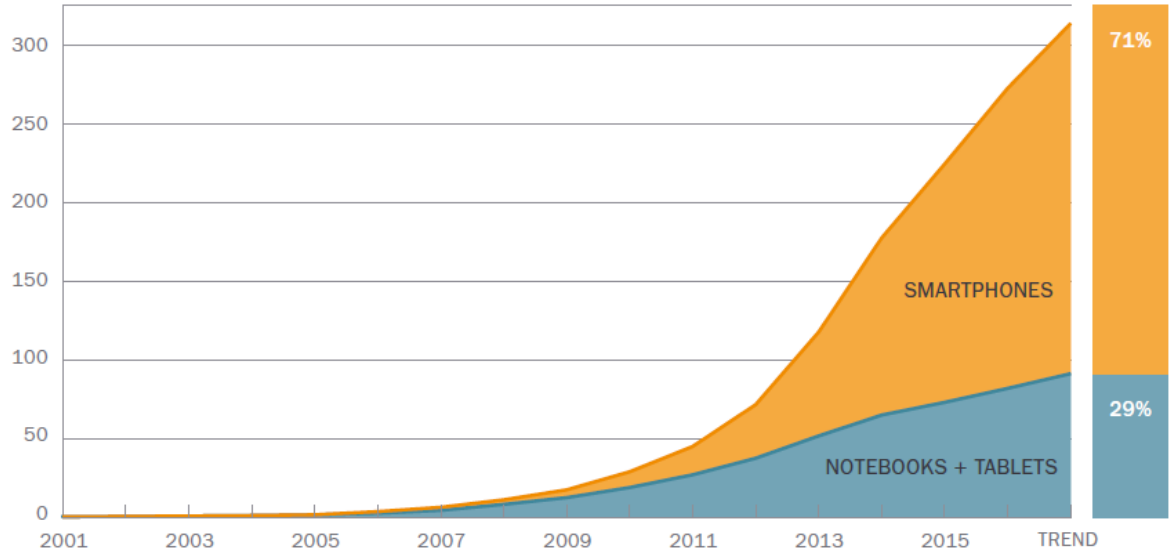

Figure 1: Wireless devices connected to the internet in use in Brazil: portable computers and smartphones in May 2016 (Millions of units) Source: ICT enterprises survey 2015.

This research has enabled the collection of quantitative and qualitative data about newly emerging behaviors, which allowed our work team to define better interfaces tools and resources according to our public needs.

The most recent publication of Brazilian Internet Steering Committee up to this date [8], brings the results of the use of ICT in enterprises and microenterprises in year 2017, indicating a scenario with two dimensions: (1) ICT has been intensely adopted, and (2) more sophisticated forms of use are still in the beginning stages. This report highlights the must to discuss ways to increase digitalization of Brazilian institutions, since expertise in digital technologies is gradually becoming a competitive advantage. ICT enterprises survey 2017 brings, as well, the challenge of improving ICT for education and learning, its contributions for workers who need to be retrained and prepared for a future of lifelong learning, and the need of least-developed countries to focus on promoting digital literacy.

> *"A critical area concerns education and training. All countries will need to adjust their education and training systems to deliver the skills required in the digital economy (Unctad, 2017c). This is vital not only for young people entering the labor market, but also for workers who need to be retrained and prepared for a future of lifelong learning that equips them for jobs and provides skill flexibility and adaptability. Priorities will vary by country. Least-developed countries may need to focus on promoting digital literacy increasing numbers of students and workers, and on building a base of ICT specialists. Policies should also expand the opportunities for workers and teachers to upgrade their skills, adapt teaching methodologies and capabilities, and seek to make future skills more attractive to students and workers. Redistribution policies may help mitigate the risk of increased polarization and income inequality."* [8].

3. DISCUSSION AND RESULTS

3.1. Learned Lessons for People with Responsibility for the Safety of Radioactive Facilities

The use of digital technology for the radiological protection programs shall help greatly the radioactive facilities. UNIPRORAD is a complete repository for research, consultation and information which provides relevant, accurate and understandable information in Portuguese. It is understandable that international organizations provide their publications in the world's most spoken languages. Nevertheless, regarding radiological protection it is very important to ensure access to information in the workers´ own language. Regarding potential exposure, occupational risks at workplace or monitoring ionizing radiation, among other vital issues, there is no space for misconceptions or misunderstandings. Radiation protection of workers should take into account lessons learned and it is a must to improve communication strategies about procedures and risks in workplace.

The radiological accident in Soreq, in Israel, illustrates the relevance of communications best strategies in workplace. This accident occurred on 21 June 1990 in an industrial irradiation facility where there were irradiated medical products and spices for sterilization purposes. The facility used an intense radioactive source ^{60}Co. According to the official report [9], the operator "*was faced with two conflicting signals, one indicating that the source was safe and one that it was not. He chose to believe that the source down signal was correct and that the radiation alarm was false.*" The operator entered the irradiation room and was acutely exposed, with an estimated whole-body dose of 10–20 Gy. The consequences were fatal. This accident, which could have been avoided, resulted from the violation of established operating procedures, followed by a series of mistakes in decision making and unauthorized actions. It is important to highlight that the operator was an experienced technician, with more than 3 years of experience, who had been trained and certified to his function. Still, violating all security procedures, he chose to enter the irradiation room. The IAEA conducted an international review in order "*to document the causes and circumstances of the accident and to draw general lessons for the benefit of those people with responsibilities for the safety of such facilities*" [9]. The commission concluded that the direct cause of the accident was given by a combination of factors that included the equipment malfunction and unauthorized actions taken by the operator. According to the IAEA report [9], the sequence leading up to the event that took place included: the transport jam that prevented the descent of the source rack into the pool; a false indication that the source rack was down; the grave misjudgment by the operator, who disregarded the radiation alarm; unauthorized action of the operator entering the irradiation room; malfunction of the portable dose rate meter; and the operator's failure to verify the portable dose rate meter before entering the irradiation room, as he was aware that the radiation alarm was running. The official report also reveals that parts of the instructions were not available in the country´s official language [9].

> "*The training courses had been given in Hebrew (the working language of the operators), but the lecture notes were in English. Similarly, the operating manual and safety instructions (parts of the instruction manual) were only available in the original English. A short list of routine operating and safety instructions, including the procedure for entering the irradiator, had been issued in Hebrew and was posted in the facility*."

This is only one, among many appropriate examples, that illustrates the importance of the themes discussed in this paper: (1) the importance of complete information always available in the workplace and in the official language of the country; and (2) the importance of preparedness to occupational risks and potential exposures, identifying possible scenarios and anticipating possible paths that may contribute to their occurrence. Most often, sequences of events can be probabilistically predicted.

3.2. Strategies to Improve Communication about Radiological Protection in Workplace

There was developed a platform whose range of features and functionality suits the needs of the corporate public. The challenge involved the ability to create a robust and effective, but at the same time flexible system, allowing to adapt it to future technological innovations. Each module has been developed independently and can be inserted, adapted, updated or deleted separately, without prejudice of the other ones. This will allow the program adjusts over time according to the needs identified during the evolution of ICT. UNIPRORAD is an open access platform that provides safe and reliable information about radiological protection, including optimization, monitoring, potential exposures and risk agents in workplace. All content that can be easily accessed, trough URL https://www.uniprorad.com.br, from any conventional internet point, with good performance even to not high-speed connections.

The project started in 2012 and UNIPRORAD was first published in 2013 for the communication of optimization programs. The content includes concepts, definitions and theory in addition to the optimization programs, help decision making techniques, information related to protection costs, radiation doses and detriment [10-13]. It was an initial core working only the optimization program, which could be extended to other fields of radiological protection, according to the positive Porphyrian Tree, published by IAEA [14] in 1990[3], the more generic and complete tree for an appropriate program of radiation protection. Furthermore, taking advantage of Internet possibilities, there were developed virtual interactive components to exercise the six quantitative decision-making techniques, according to the ICRP recommendations [11], so the user can quantify and sense the extent required in practical situations. These interactive components were original and have been exclusively created for this purpose.

From 2014 to 2015, this web-based-project counted already on ionizing radiation monitoring policy and techniques, integrating and interrelating elements of optimization and monitoring programs. The monitoring content presents the criteria used for control of occupational exposures, 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 (monitoring for external radiation, monitoring for surface contamination and monitoring for air contamination) and individual monitoring (monitoring of external exposure and monitoring of internal exposure and monitoring for skin and clothing), discussing objectives, routine monitoring, task-related monitoring, special monitoring and interpretation of results for each type of monitoring program. In addition, problem-based training interactive exercises about external radiation and air contamination are given, helping users to develop necessary skills for achieving higher performance in workplace [15–16].

[3] Even tough IAEA Publication 102 is superseded, the recommendations regarding a tree for an appropriate and effective radiation protection program are not repeated in the newest publications of this entity.

In 2017 the research team for potential exposures of the Nuclear and Energy Research Institute (IPEN-CNEN/SP) started to disseminate through the website reliable information about potential exposure, discussing not only the collection and interrelationship of existing information in the several publications (IAEA and ICRP), but also new approaches from some recommendations, due to the fact that 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. The information program offered by UNIPRORAD proposes the development of fault trees and the analysis of different scenarios. As an example, our work group present deeper discussions about the fault trees presented in ICPR Publication 76, suggesting different paths to quantify probabilistically the occurrence of potential exposures [17-21].

In 2019 our workgroup initiated some actions focusing the communication of risk agents in workplace. Regarding potential exposures, it is essential to take into account the concept of "risk", which seems to assume a great variety of meanings, even among experts. The impasses to communicate the concept of risk for radiological protection purposes, can be given by the following examples:

- ICRP 64 - (section 7)
  "Before ICRP 60, the Commission used the term "risk" as a synonym for the probability of a harmful effect (fatal cancer or severe hereditary damage). Nevertheless, outside radiation protection field, "risk" has several meanings, including the common sense in everyday language, meaning an undesirable event, including both the probability and the nature of an event. In nuclear safety, "risk" is mostly defined as the mathematical expectation of the magnitude of the undesirable consequence, which means: the product of the probability and the consequence of the event. In this sense, risk becomes a physical quantity characterized by a magnitude expressed by a unit with no dimension when risk means probability, but with a certain dimension if it means the mathematical expectation of the consequence. This publication already recognized that these different meanings of the word causes considerable confusion in interdisciplinary communications" [17].

- INSAG 9 - (section 6)
  "The word "risk" has several meanings, even though to all of them there is an associated idea of probability. In a number of publications, "risk" is used as synonym of "an event probability with undesirable consequences". In nuclear safety, it is often employed meaning a combination of probability and consequences, sometimes presented as a product of the probability of an event and the magnitude of its consequence. This product is the mathematical expectation of the consequences" [20].

- NEA / OECD – (section 4.1)
  "The word "risk" can be used in a variety of ways and be given several meanings. In the common loose meaning of everyday language, it is the thread of an undesirable outcome, e.g. death or adverse economic consequences. Two common definitions of risk used in technical work are: (a) the probability of a defined unwanted consequence, and (b) the mathematical expectation of consequences, i.e. the annual probability of an accident multiplied by a measure of the consequences if the accident occurs" [19].

Regarding the issue, the web-based program UNIPRORAD offers a further approach among several publications, discussing and explaining their concepts, definitions and recommendations. About risk agents in workplace, the website discusses combined exposures, more specifically, the biological effects of radiation in combination with other agents: physical (ionizing radiation, ultraviolet radiation, electromagnetic radiation, among others), chemical (genotoxic substances and non-genotoxic substances) and biological (such as the action of viruses and bacteria). Numerous examples of combined exposures to radiation can be found in the literature. There are, for instance, a vast material about tobacco and radon, as well as toxic metals or combinations of different types of ionizing radiation. The development of this research and implementation of the proposed theme about radiological protection is a long and difficult task, which implies working complex content through relational database, as well as the inter-relationship of all related information, from national and international publications, concerning the combined exposures in workplace.

3. CONCLUSIONS

UNIPRORAD is an educational action in accordance with the latest official government reports regarding the use of digital media to enhance the dissemination of information. Indeed, ICT can contribute to universal access to education, contributing to achieve both the delivery of high-quality information and the possibility of professional development. The system is entirely designed to provide reliable information to Brazilian facilities considering two mainly objectives: (1) the opportunity to have access to all content in Portuguese, the official language of our country, and (2) updated information interrelating the content from different publications concerning radiological protection and radiological safety.

Reliable information in Portuguese helps to prevent miscommunication and common mistakes committed by many non-native English speakers. Indeed, when readers do not share a native language, analysis and interpretation of the data can lead to misunderstandings, non-understandings or false cognates which can originate non-desirable situations. Obtaining a quality education is the foundation to creating sustainable safe culture in workplace.

Over the years, the system has constantly been updated with content of interest about radiological protection programs, such as optimization, ionizing radiation monitoring, potential exposure and risks agents in workplace. From this point on, the work involves managing the current needs and anticipating future perspectives to implement new actions and strategies to enhance a quality education, spreading information wherever it is needed to inform as many people as possible, contributing to develop workers´ professional skills.

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