International Journal of Business, Human and Social Sciences
ISSN: 2517-9411
Vol:11, No:1, 2017

Web-Based Instructional Program to Improve Professional Development: Recommendations and Standards for Radioactive Facilities in Brazil

Denise Levy, Gian M. A. A. Sordi

Abstract**—**This web based project focuses on continuing corporate education and improving workers' skills in Brazilian radioactive facilities throughout the country. The potential of Information and Communication Technologies (ICTs) shall contribute to improve the global communication in this very large country, where it is a strong challenge to ensure high quality professional information to as many people as possible. The main objective of this system is to provide Brazilian radioactive facilities a complete web-based repository - in Portuguese - for research, consultation and information, offering conditions for learning and improving professional and personal skills. UNIPRORAD is a web based system to offer unified programs and inter-related information about radiological protection programs. The content includes the best practices for radioactive facilities in order to meet both national standards and international recommendations published by different organizations over the past decades: International Commission on Radiological Protection (ICRP), International Atomic Energy Agency (IAEA) and National Nuclear Energy Commission (CNEN). The website counts on concepts, definitions and theory about optimization and ionizing radiation monitoring procedures. Moreover, the content presents further discussions related to some national and international recommendations, such as potential exposure, which is currently one of the most important research fields in radiological protection. Only two publications of ICRP develop expressively the issue and there is still a lack of knowledge of fail probabilities, for there are still uncertainties to find effective paths to quantify probabilistically the occurrence of potential exposures and the probabilities to reach a certain level of dose. To respond to this challenge, this project discusses and introduces potential exposures in a more quantitative way than national and international recommendations. Articulating ICRP and AIEA valid recommendations and official reports, in addition to scientific papers published in major international congresses, the website discusses and suggests a number of effective actions towards safety which can be incorporated into labor practice. The WEB platform was created according to corporate public needs, taking into account the development of a robust but flexible system, which can be easily adapted to future demands. ICTs provide a vast array of new communication capabilities and allow to spread information to as many people as possible at low costs and high quality communication. This initiative shall provide opportunities for employees to increase professional skills, stimulating development in this large country where it is an enormous challenge to ensure effective and updated information to geographically distant facilities, minimizing costs and optimizing results.

Denise Levy is with the Nuclear and Energetic Research Institute (IPEN – CNEN - SP) São Paulo, Brazil (phone: 55-11-993564042; e-mail: denise@omiccron.com.br).

Gian Maria Agostino Angelo Sordi is with the Nuclear and Energetic Research Institute (IPEN – CNEN - SP) São Paulo, Brazil (e-mail: sssylvia1@hotmail.com).

Keywords**—**Distance learning, information and communication technology, nuclear science, radioactive facilities.

I. Introduction

THIS paper focuses on the potential value of ICTs to enhance communication and education on Radiological Protection for Brazilian radioactive facilities. Brazil is a large country with geographically distant states and hundreds of radioactive facilities. The project UNIPRORAD (Unification of Radiological Protection Programs) is a web-based tool to spread information and communication on radiological protection and safety for these radioactive facilities all over the country [1].

In Brazil, there is a conceptual difference between nuclear and radioactive facilities. Nuclear facilities comprise the entire nuclear fuel cycle, including nuclear materials mining, power reactors, the production of radioisotopes and the reprocessing of fuel elements of nuclear reactors. Radioactive facilities can be defined as those which make use of ionizing radiation in other peaceful applications of nuclear energy such as industry, medicine, agriculture and environmental protection, among others. This difference is due to the fact that the entire nuclear fuel cycle, including reactors, are government monopoly. All other activities involving ionizing radiation can be developed and used by the public, under the national regulatory body supervision [2].

In order to establish a Radiation Protection Plan or a Radiation Emergency Plan, Brazilian radioactive 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 ICRP, the IAEA and the CNEN.

The ICRP recommendations of radiation protection are based on the reports of the United Nations Scientific Committee on the Effects of Atomic Radiation (UNSCEAR) and reports of the Biological Effects of Ionizing Radiations (BEIR), aimed to protect the environment and individuals to the harmful effects produced by ionizing radiation. Its recommendations establish the standards for radiation protection taking into account the plural aspects related to radiation health effects, protection in medicine and protection of the environment, among others. This entity has published more than 110 reports, although many of them are considered superseded.

Based on ICRP reports, the IAEA develops its own recommendations and requirements. The IAEA has a technical cooperation agreement with the United Nations and its publications are destined to all UN state members. Regarding radiological operational protection, there is the collection IAEA Safety Series (with more than 150 publications), as well as the collections IAEA Technical Report Series and the technical documents series known as Tec-doc. Nevertheless, some of the publications are already superseded.

Every country affiliated with the UN establishes its national regulations according to the international ICRP and IAEA recommendations. Each country has its own regulatory body, which should be in permanent contact with the IAEA. In Brazil, the national entity linked to the IAEA, is the CNEN. This committee has issued the national standards for radioactive facilities in the country. CNEN´s requirements are adequate and effective for radiological protection operations, but even though the Basic Guidelines Protection inform the requirements for a Radiation Protection Plan, they are not in a logical sequence, nor have detailed and specific comments. As similar radioactive facilities may have different descriptions to have their programs approved, getting appropriate and complete information is a must and a challenge.

This project aims the collection of the radiological protection programs in a single system in order to offer unified and inter-related information in Portuguese, providing Brazilian radioactive facilities a single web-based tool for research, consultation and information which allows continuing professional development. Moreover, aside from the established radiological programs, the content presents new approaches from some recommendations, discussing appropriate actions towards safety to be incorporated into labor practice, such as an auditing function and preparedness to potential exposures. These issues are not expressively discussed in national or international publications. Even though publications provide fundamental theory, they are incomplete in their examples, making it difficult to discuss information in a complete and clear way, even from the original publications.

This web based project focuses on the potential value of ICTs to enhance communication and education on Radiological Protection throughout Brazil. ICTs present unprecedented opportunities to innovate solutions to spread scientific content minimizing costs and optimizing results.

II. Problem Statement

The use of information technology for the radiological protection programs shall greatly help the radioactive facilities. The following example illustrates the value of knowledge dissemination in the workplace in a complete and comprehensive way.

The radiological accident in Soreq, Israel, occurred on 21 June 1990 in an industrial irradiation facility where there were irradiated medical products and chemicals for sterilization purposes. The facility used an intense radioactive source ^{60}Co. According to the official report [3], the operator, a trained technician with more than three years of experience, "*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. The operator was an experienced technician 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*" [3].

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 [3], 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 [3].

> *"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, in all its dimensions.

- The importance of complete information always available in the workplace and in the official language of the country.
- The importance of an auditing function, strongly recommended in this IAEA report: "*audits are an indicator to staff of the importance that management attaches to radiation safety to support the quality of the function related to the task and the veracity of the reports provided*".
- The importance of preparedness to potential exposures, identifying possible scenarios and anticipating possible paths that may contribute to their occurrence. Most often, potential exposures following sequences of events can be probabilistically predicted.

III. Content Development

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.

The content includes concepts, definitions and theory about the optimization programs and help decision-making techniques, including the various aspects of optimization, as:

- The basic principles of radiological protection, as provided by the publication ICRP 22 [5].
- Quantitative decision making techniques, according to the publications ICRP 22 and ICRP 55 [3], [6].
- Implications of the alpha value[1] according to the publication of the Commission of European Communities [7] and the IAEA guidelines [8].
- The methodology to implement the optimization procedure for the project and the operation in a radioactive facility [8], [9].
- The methodology for the construction of the optimization process, considering its features, stakeholders and the distribution of doses over time and space, according to publication of the ICRP [9].
- The procedures to evaluate exposure situations and the principles and paths to reduce exposure [8], [9].
- The global components to consider, define and implement an ALARA[2] Program [5]-[9].

In addition, there were created Problem Based Learning interactive exercises and interactive virtual simulators, which allow the user to experience different scenarios and situations, to reinforce concepts and to extend the acquired knowledge to practical implementation of radiation protection [1].

The content includes, as well, concepts, definitions and theory about the ionizing radiation monitoring policy and techniques. In order to introduce the basic concepts of monitoring, the system presents the criteria used for the control of occupational exposures, discussing normal and potential exposures, authority and responsibility, classification of work areas, practical implications and engineering controls, operational procedures, reference levels, types of monitoring and its functions. Users are given 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). For each type of monitoring, the user is given detailed information, including the main objectives, routine monitoring, task-related monitoring, special monitoring and interpretation of results [10]-[13]. Furthermore, in order to help users to increase their understanding about monitoring programs, it was created exclusively for this purpose, an interactive virtual component presenting hypothetical problem-based situations related to workplace monitoring for air contamination and workplace monitoring for external radiation.

IV. Further Discussions

Aside from the repository of radiological protection programs, the website presents new approaches from some international recommendations, discussing appropriate actions towards safety which could incorporated into labor practice. In this sense, it is discussed the benefit of an auditor monitoring. Respecting the scope of the principles of radiological protection, an auditing program permits to evaluate whether criteria and actions previously established by Radiological Protection Service are effectively implemented and remain appropriate as time goes by. The results of auditing procedures help to detect deficiencies in the process, enabling conclusions and recommendations, and avoiding possible triggers of undue exposures. Through systematic examinations of activities in each type of monitoring, auditing helps to ensure the process, supporting the employee in performing task-related monitoring and also supporting the facility that chooses responsible actions towards safety.

Another issue, which currently constitutes one of the most important research fields in radiological protection, is potential exposure. Only a few international publications have expressively developed the issue. One of the problems considered is the lack of a common understanding about definitions and terms used, which sometimes seem to have different meanings in the different communities. Therefore, regarding professional developing, this educational website brings further discussions of some terminologies, such as individual risk, safety, probability, frequency, event, sequence, scenario, consequence, limits and constraints, among others. Furthermore, there has been made a comprehensive research in order to articulate existing information from ICRP and AIEA valid recommendations and official reports in order to discuss this subject, introducing potential exposures in more quantitative ways than national and international recommendations. The discussions are based on the following publications:

- Publication ICRP 60, which gives the first basic steps to develop potential exposures issues [14];
- Publication ICRP 64, focusing risks, probabilities, defense-in-depth and safety culture [15];
- INSAG 9, published by the International Nuclear Safety Advisory Group, a report on potential exposure in nuclear safety to complement IAEA's work on safety standards about potential exposure, discussing risks and probabilities and establishing policies for nuclear and radiation safety [16];
- Report from CRPPH/CSNI/CNRA/RWMC Expert Group, published by OECD/ NEA, discussing the meaning and application of the concept of potential exposure, according to Publications ICRP 60, ICRP 64, AIEA SS114 and AIEA INSAG-9 [17];
- Publication ICRP 76, which presents fault tree analyses

[1] The Alpha Value is the monetary value of a person-sievert, used to determine the cost to be invested in a practice to minimize radiation doses to acceptable levels.

[2] ALARA is an acronym for “As Low As Reasonably Achievable”. According to the publication ICRP 22 radiation exposure must be kept as low as reasonably achievable, taking economic and social factors into account.

with five different applied examples [18].

Moreover, the system offers the development of fault trees, suggesting complete and general scenarios constructions that could be extended and applied by similarity to any radioactive facility according to its specific situation. The scenarios are developed taking into account international recommendations from three different publications:

- ICRP 76: using the fault tree analysis of the radiotherapy device, fault tree analysis of a modern irradiator and fault tree analysis of an accelerator for isotope production [18];
- AIEA 102: respecting the positive tree published by in 1990, considered the most generic and complete tree for an appropriate program of radiation protection [4];
- AIEA TECDOC 430: according to the requirements and for the correct development of a fault tree [19].

V. Website Monitoring Results

The project UNIPRORAD [1] counts on modern educational technology concepts, providing Brazilian radioactive facilities a complete repository for research, consultation and information in a quick, integrated and efficient way. The web platform tools and functionalities have been developed to meet the corporative public needs, according to the results provided by investigations of users´ profiles. Google Analytics was considered to be the best tool for monitoring the system. However, due to a deluge of referral spams since year 2015, customized filters were created in order to obtain accurate and reliable data from Analytics´ reports. In 2015, between June 15 and July 14, the site UNIPRORAD received 125 visitors, among them 31.34% returning visitors, which registered a total of 5,481views, as seen in Fig. 1. The most recent report up to this date brings the audience overview of the same period in year 2016, when the website counted on 239 visits from 140 users, among which 53.97% were returning visitors, with an average session duration of 13:56 minutes, and an average of 9.91 page views per session, as seen in Fig. 2. Moreover, Google Analytics reports information about users´ operational systems profiles, services providers and screen resolutions, providing fundamental information for strategical planning of the evolution of this project, as the web platform tools and functionalities must be developed according to the target public needs.

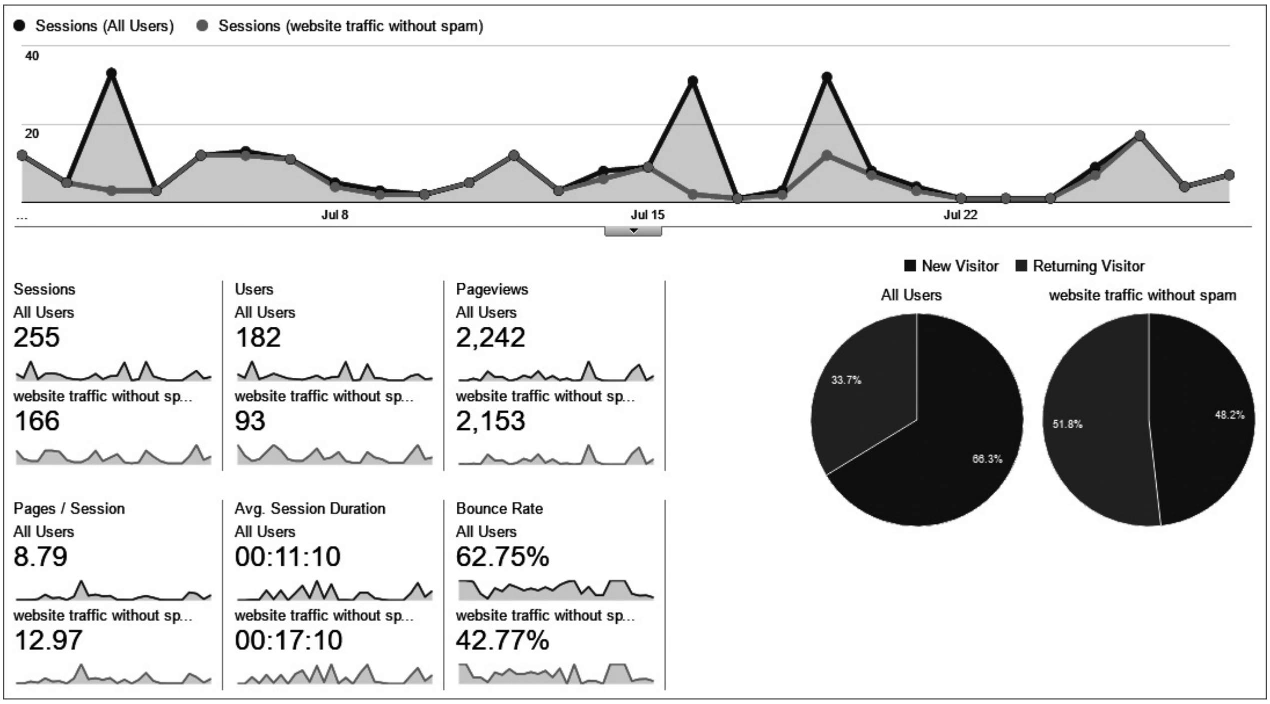

Fig. 1 Google Analytics report from 15/06/2015 to 14/07/2015

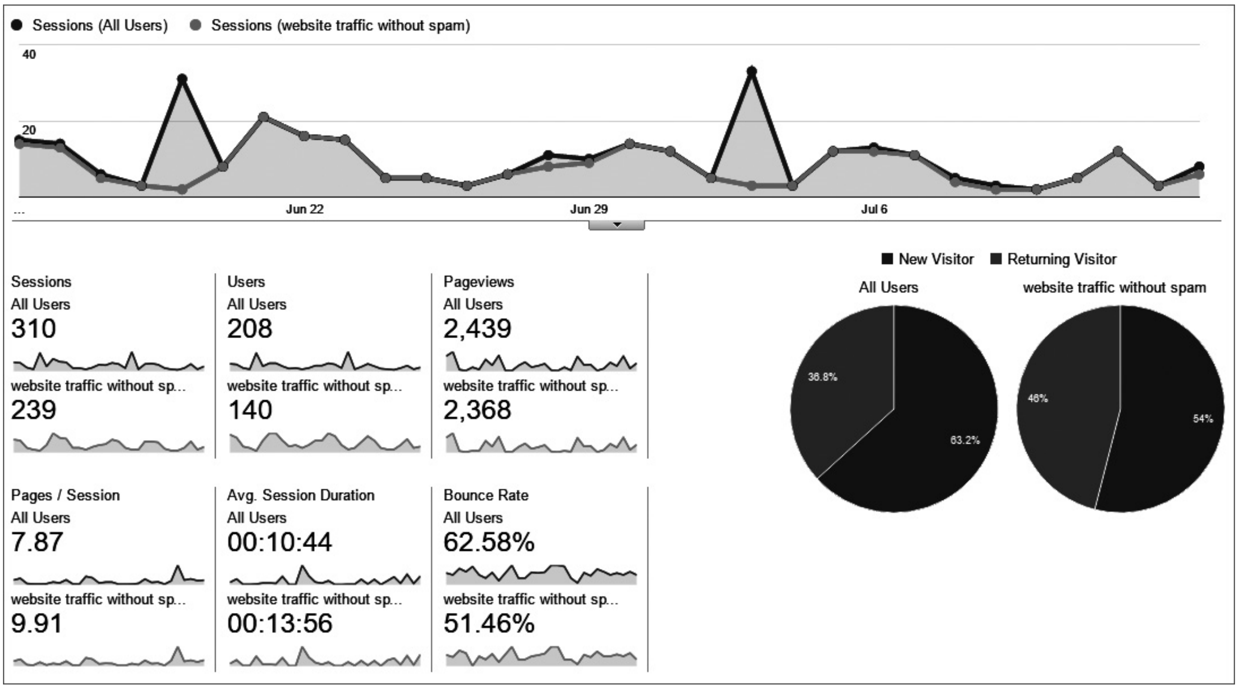

Fig. 2 Google Analytics report from 15/06/2016 to 14/07/2016

VI. Final Considerations

When the system was first implemented as a pilot project in 2012, ICTs in Brazilian companies were a trend, but still not a reality.

According to several publications held by the Brazilian Internet Steering Committee, who conducted several surveys in all Brazilian States, there was an important advance in the use of ICT in Brazilian companies [20]-[23]. These surveys made use of methodological standards proposed by the United Nations Conference on Trade and Development (UNCTAD), a coalition of international organizations aiming the harmonization of key indicators on ICT research.

In Brazil, between years 2006 and 2008 there was a significant decrease in the use of the dial-up internet from 14% to only 5% [20]. Besides, there was significant progress regarding internal wireless network in corporations, from 14% in 2005 [21] 41% in 2009 [20]. In year 2010, 97% of Brazilian companies with more than 10 employees used computers and this percentage increased to 100% for companies with more than 50 employees [21]. The average percentage of employees, who used computers in the workplace, was equivalent to 45% [21]. Access to Internet was about 40% in South and Southeast regions and the Midwest region showed the highest average rate with 43% of employees using the Internet in the workplace [21]. Some 86% of Brazilian companies were already making great use of the Internet to search for professional information [21]. In 2011, 13% of employees claimed to use corporate cellphones and tablets, and in 2012 this proportion increased to 19% [22], [23]. These are only few examples that demonstrate the rapid evolution and trends of the business market regarding technological trends from 2008 to 2012. This was the scenario when the pioneer project was first implemented and ICTs possibilities keep growing ever since.

The authors of this web-based educational program believe in the growing potential of ICTs to disseminate information throughout Brazil, contributing to deliver information where it is needed and stimulating development to all aspects of the Brazilian society. Making use of the Internet, wireless networks, cell phones and other digital media, ICTs provide a huge array of new communication possibilities, spreading information to geographically distant regions at low costs and high quality communication. Regarding radiation protection, ICTs offer unprecedented opportunities to education and conditions for improving professional and personal skills in this large country where it is still a strong challenge to ensure access to information to as many people as possible, minimizing costs and optimizing results. This pioneer project shall help greatly Brazilian radioactive facilities and it is our target to make it an international reference for Portuguese spoken countries.

References

[1] D. S. Levy, "UNIPRORAD – Unificação dos Programas de Proteção Radiológica". Available in: http://www.uniprorad.com.br (2012) Last accessed in July 2016.

[2] D. S. Levy, G.M.A.A. Sordi, A.L.C.H. Villavicencio, F. Biazzini Filho, "Web-Based Communication Systems: Innovative Solutions to Complex Development Challenges" *In*: X Congreso Regional Latinoamericano IRPA de Protección y Seguridad Radiológica, Argentina, 2015.

[3] International Atomic Energy Agency. "The radiological accident in Soreq". Vienna, 1993.

[4] International Atomic Energy Agency. "Safety Series 102: Recommendation for the Safe Use and Regulation of the Radiation Source in Industry, Medicine and Teaching", Vienna, 1990.

[5] International Commission on Radiological Protection. "Implications of Commission Recommendations That Dosis Be Kept as Low as Readily Achievable", publication ICRP 22. Vienna, 1973.
[6] International Commission on Radiological Protection. "Optimization and Decision-Making in Radiological Protection, publication", ICRP 55 Ann. ICRP 20 (1), Vienna, 1990.
[7] Commission of the European Communities, "Radiation Protection: ALARA from Theory Towards Practice", Report EUR 13796EN, Luxemburgo, 1991.
[8] International atomic energy agency, "Safety Report Series n. 21: The optimization of the Radiation Protection in the Control of Occupational Exposure", Vienna, 2002.
[9] International Commission on Radiological Protection, "The optimization of the Radiological Protection: Broadening the Process", publication ICRP 101b, Ann. ICRP 36 (3). Vienna, 2006.
[10] International Commission on Radiological Protection, "General Principles for the Radiation Protection of Workers", publication ICRP 75, Vienna, 1997.
[11] Comissão Nacional de Energia Nuclear, "NN 3.01: Diretrizes Básicas de Proteção Radiológica", Rio de Janeiro, 2011.
[12] International Commission on Radiological Protection, "The 2007 Recommendations of the International Commission on Radiological Protection", publication ICRP 103, Vienna, 2007.
[13] International atomic energy Agency, "Safety Standards for Protecting people and the environment – Radiation protection and safety of radiation sources, GSR – Part 3", Vienna, 2014.
[14] International Commission on Radiological protection, "Recommendations of the International Commision on Radiological Protection Publication", ICRP Publication 60, Vienna, 1991.
[15] International Commission on Radiological Protection, "Protection from Potential Exposure - A Conceptual Framework", ICRP Publication 64, Vienna, 1993.
[16] International Atomic Energy Agency, "Potential Exposure in Nuclear Safety - A report by the International Nuclear Safety Advisory Group", INSAG-9, Vienna, 1995.
[17] Ocde, Nea, "The meaning and application of the concept of potential exposure", CRPPH/CSNI/CNRA/RWMC Expert Group, Paris, 1995.
[18] International Commission on Radiological Protection, "Protection from Potential Exposures - Application to Selected Radiation Sources", ICRP Publication 76 Ann. ICRP 27 (2), Vienna, 1997.
[19] International Atomic Energy Agency, "Procedures for the systematic appraisal of operational radiation protection programmes, IAEA TECDOC 430", Vienna, 1987.
[20] Comitê Gestor da Internet no Brasil, "Pesquisa Sobre o Uso das Tecnologias da Informação e da Comunicação no Brasil 2009", http://www.cetic.br/publicacao/pesquisa-sobre-o-uso-das-tecnologias-da-informacao-e-da-comunicacao-no-brasil-2009/ (2010) Last accessed in July 2016.
[21] Comitê Gestor da Internet no Brasil. "Pesquisa sobre o uso das Tecnologias de Informação e Comunicação no Brasil - TIC Domicílios e Empresas 2010", http://www.cetic.br/publicacao/pesquisa-sobre-o-uso-das-tecnologias-da-informacao-e-da-comunicacao-no-brasil-tic-domicilios-e-empresas-2010/ (2011) Last accessed in July 2016.
[22] Comitê Gestor da Internet no Brasil. Pesquisa sobre o uso das Tecnologias de Informação e Comunicação no Brasil - TIC Domicílios e Empresas 2011, http://www.cetic.br/publicacao/pesquisa-sobre-o-uso-das-tecnologias-da-informacao-e-da-comunicacao-no-brasil-tic-domicilios-e-empresas-2011/ (2012) Last accessed in July 2016.
[23] Comitê Gestor da Internet no Brasil. Pesquisa sobre o uso das Tecnologias de Informação e Comunicação no Brasil - TIC Domicílios e Empresas 2012, http://www.cetic.br/publicacao/pesquisa-sobre-o-uso-das-tecnologias-de-informacao-e-comunicacao-no-brasil-tic-domicilios-e-empresas-2012 (2013) Last accessed in July 2016.