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USE OF REPORTS ON ACCIDENTS WITH SEALED SOURCES TO CONCEIVE SCENARIOS OF HUMAN INTRUSION INTO WASTE REPOSITORIES

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ABSTRACT

The Radioactive Waste Management Department (GRR) at the Nuclear and Energy Research Institute (IPEN) develops the concept of a repository for disposal of disused sealed radioactive sources (SRS) in a deep borehole. In this concept, the estimated few hundred thousand SRS of the Brazilian inventory will be packaged in lead containers stacked in an encased and cemented borehole, drilled to a depth of a few hundred meters, in a crystalline bedrock geological setting. A generic safety analysis for this concept of repository must achieve two goals: to be acceptable by regulatory bodies and be simple enough so that the engineering of licensing a facility has technical and economical feasibility. It must be kept in mind that the disposition of the SRS must be paid by the users of the sources, and that the costs of applying the existing methods for the performance and safety assessment of a geological repository dedicated exclusively for sealed sources may be exceedingly high. In this respect, the disposal concept development work includes the search for methodologies that could be applied to the disposal facility for demonstrating safety without unduly increasing the project costs. One line of research is to identify and characterize human intrusion scenarios that could result in significant radiation exposures. Results of a survey on the published literature and on databases of reported accidents involving sealed sources are being used to construct a number of model accident scenarios with which the time evolution of the exposure risks can be assessed for each radioisotope inventory and each relevant disposed of source. Among the 252 accident descriptions recovered in the survey, the 1954 Russian accident report with Po-210 is the oldest, and that of the 2010 accident in Mayapuri, India, with a Co-60 source is the latest. The results of this assessment will be used as a safety indicator of the disposal concept.

1. INTRODUCTION

The Radioactive Waste Management Department (GRR) at the Institute of Energy and Nuclear Research (IPEN) develops the concept of a repository for disposal of disused sealed radioactive sources (SRS) in a deep borehole. In this concept, the estimated few hundred thousand SRS of the Brazilian inventory will be packaged in lead containers stacked in an encased and cemented borehole, drilled to a depth of a few hundred meters, in a crystalline bedrock geological setting.

A generic safety analysis for this concept of repository must achieve two goals: be acceptable by regulatory bodies and simple enough so that the engineering of licensing a facility has technical and economical feasibility. It must be kept in mind that the disposition of the SRS must be paid by the users of the sources, and that the costs of applying the existing methods for the performance and safety assessment of a geological repository dedicated exclusively for sealed sources may be exceedingly high.

The work undertaken at GRR to develop the disposal concept includes the search for methodologies that could be applied to the disposal facility for demonstrating safety without unduly increasing the project costs. One line of research is to identify and characterize human intrusion scenarios that could result in significant radiation exposures. The doses resulting from scenarios of human intrusion in the repository is one of the safety indicators that has been proposed by Leite et al [1] as complementary tool for the safety analysis of deep boreholes for disposal of sealed sources.

Previously, one of the authors [2] proposed two scenarios of human intrusion in a shallow ground disposal facility. Both scenarios derive from the assumption that extensive future earth works will break the isolation of the repository, exposing part of the sources to the accessible environment. In one scenario, a worker picks up one source from the ground and kept it in his pocket for eight hours. In the other, the individual works at one meter from the source for one hour.

However, these two scenarios lack some indication of conservatism (or otherwise optimism) in the model used to calculate the incurred doses, as to show that the source disposal method is acceptable. A search in the literature for examples of studies on human intrusion into repositories proved fruitless which led to the search of an alternative approach.
The new approach consisted in collecting data on accidents with sealed sources reported in the literature. Although the impact of most of them is limited either in relation to human health or in respect to environmental contamination, the number of accidents with sealed sources is relevant. A preliminary inspection in the databases of accidents showed that these data could supply useful information to support the design of scenarios of intrusion into repositories.

The expected outcome of such approach is one answer to the ‘what if’ question for the case of intrusion, as a consequence, for instance, of extensive earth works in the repository site that break the isolation of the sources. It is important to stress that the point hear is what could happen if the isolation is broken, independently of what causes the break up of the isolation.

This paper presents the results of a search in databases of radiological accidents, which retrieved 252 accident or incident cases, reported since 1954, and that were considered relevant examples of exposure of individuals to sealed sources. The purpose of the research was to gather information for designing scenarios of human intrusion in a repository for disused sealed sources [3].

2. METHODS

Relevant accidents or incidents with sealed sources were initially retrieved from a web page maintained by Johnston [4]. This web site is dedicated to radiation accidents and other events causing radiation casualties. All entries in the database of that website were examined and those related to sealed sources were selected to further analysis. Complementary information of each reported case was collected from other sources, mainly from citations in each entry. The bibliography included books, thesis and dissertations, papers in scientific journals, and pages in the Internet. They were retrieved with the aid of the web searching engines, the International Nuclear Information System (INIS), and the IPEN library collection index. The same was applied to the books published by the IAEA on the subject [5-28].

Results were tabulated in an Excel worksheet. For each of the 252 entries, the following pieces of information were recorded:

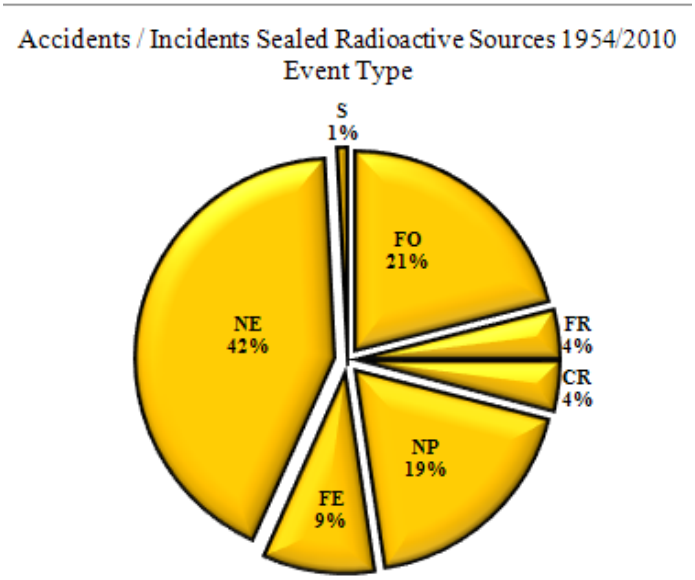
1. The date and the place (country and region or city) of the accident;
2. Causes of the accident (orphaned sources, equipment failure, neglected protocols, etc.)
3. Source radioisotope and activity;
4. Exposed individuals (public or OEI);
5. Exposure time and distance from the source;
6. Number of exposed individuals and classification of the severity of exposure;
7. Doses incurred and incidence of effects (death, amputations, cancer, sterility)

A comprehensive table of the recorded data and results is presented elsewhere [3]. A summary of the results of the search are presented below.

3. RESULTS

There are many reports that were difficult to retrieve and the analysis of available reports on the accidents with sealed sources revealed that they are mostly incomplete, with potentially valuable pieces of information to the scientific community being lost. The conditions that have led to the accidents once clearly described, always they were known, could provide invaluable lessons to aid in preventing their repetition or could furnish helpful clues on the preparedness to respond to such events. In the present case, they could also provide a basis for the design of exposure models in human intrusion scenarios for the safety analysis of repositories.

Notwithstanding the scarceness of complete and consistent data, the analysis undertook in this work yielded satisfactory results. Two hundred fifty two cases were selected among the accidents and incidents involving sealed sources in the period from 1954 to 2010.
The distribution of causes among the reported accidents and incidents that have been selected is shown in figure 1.



NE: Unspecified causes FE: Equipment Failure FO: Orphaned source FR: Stolen Source CR: Crime NP: Neglect Protocol S: Suicide

Figure 1. Reported causes of the selected accidents.

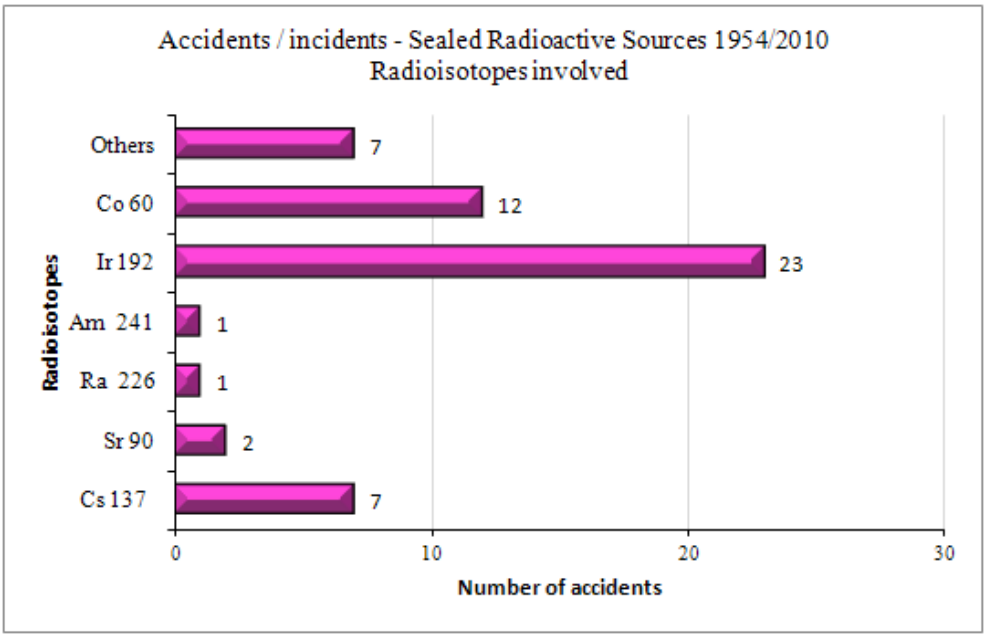


Figure 2. Radioisotopes present in sealed sources involved in the analyzed reports

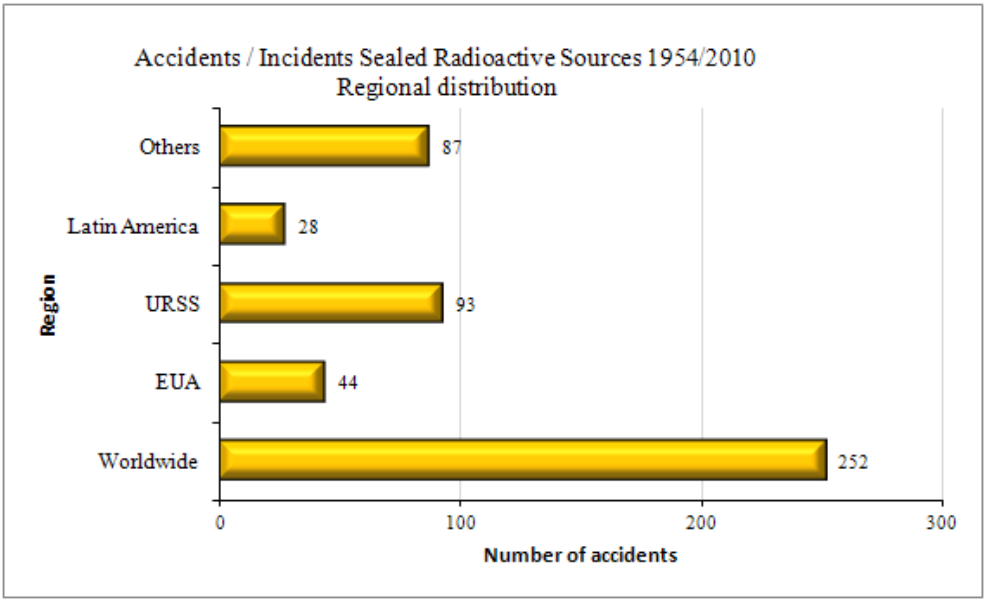


Figure 3. Regional distribuition of all reported accidents.

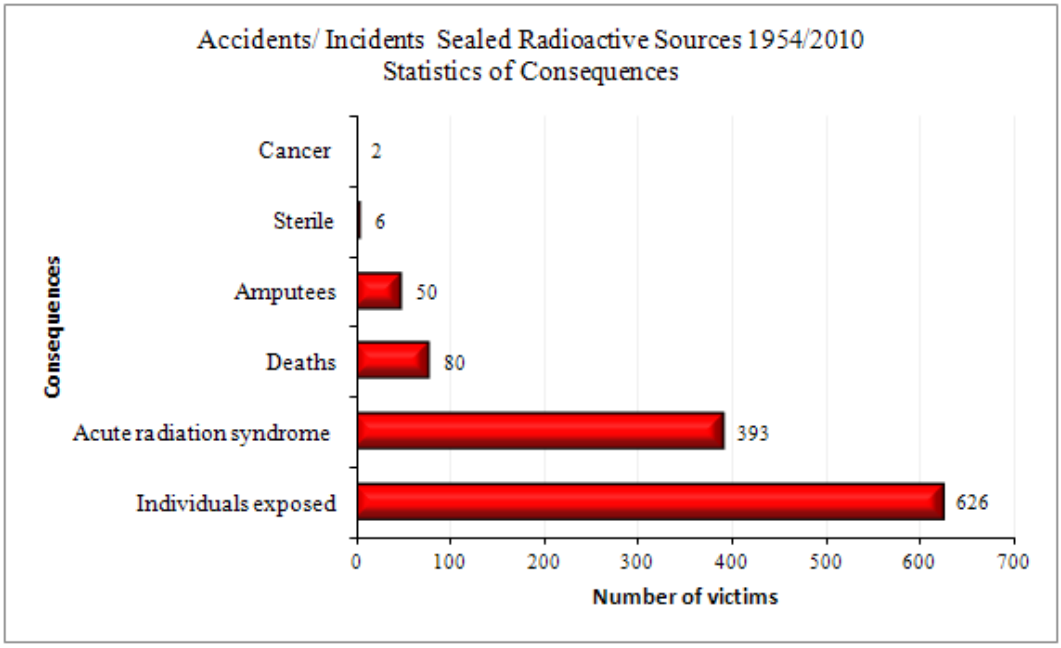


Figure 4. Statistics of consequences of all reported accidents.

As can be seen, the number of accidents with no reported cause is a large fraction of the analyzed cases and only accidents with causes clearly indicated were used to derive scenarios of exposure.

Most accidents occurred with sealed sources while they were still in use and under the responsibility of the licensees, a smaller number of accidents occurred after the sources had been declared disused or have been discarded as radioactive waste. Orphaned sources caused most of the accidents the larger number of casualties and fatal victims.

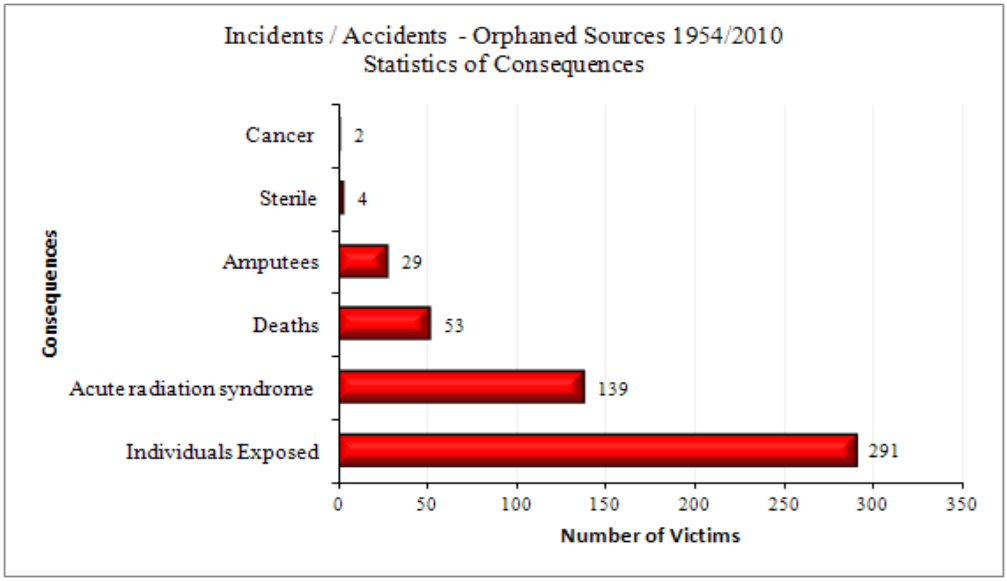


Figure 5. Statistics of consequences of all reported accidents with orphaned sources

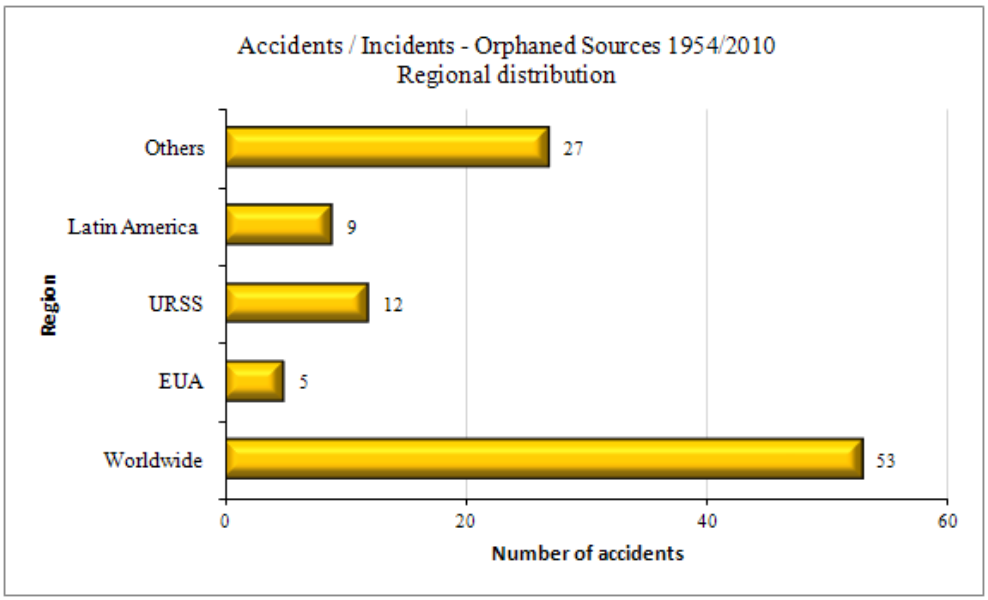


Figure 6 –Regional distribution of reported accidents with orphaned sources.

4. CONCLUSIONS

Accidents and incidents of interest to the present work were those caused by orphaned sources because they better represent the events that could happen in a scenario of human intrusion into a repository for sealed sources.

The management of the risk of disused sealed sources is a challenge for many countries, considering that most countries still lack a final disposal route for them. In spite of the many interim storage facilities that have recently been built with enhanced safety and security features, the interim storage is, though necessary, only an intermediate step, and there is no better alternative than the final disposal. Actually, the final disposal is recognized as the safest option for all wastes, with the exception perhaps of short lived wastes that can be managed by delay/decay/release.

Long-lived sealed sources have as yet no alternative for final disposal in the most countries and specific solutions must be developed and implemented. When mishandled, these sources can cause severe accidents with fatalities, injuries and economic loss as a consequence of contamination of large areas [29].

The magnitude of the safety aspects of disused sealed radioactive sources were clearly dimensioned in the International conference on the safety of radiation sources and security of radioactive materials, held in Vienna, in 1998 [30]. As it was stated there, much attention has been paid to the risks of the nuclear fuel cycle to protect human health and environmental safety, but the risks associated with radiation sources outside the fuel cycle should not be overlooked. While the hazards associated with the nuclear fuel cycle are well documented and with the exception of nuclear powered ships, all nuclear reactors and other nuclear facilities are at well known, fixed locations, many radiologically relevant sealed sources were

not. The lack of a final disposal option for disused sealed sources is the consequence of that negligence.

Accidents with disused, orphaned or stolen sealed sources being melt in recycling metal furnaces are a world wide problem. Users of sealed sources are many, in a number of different applications in medicine, industry, research and others. Mishandling and negligence some times lead to serious exposures to radiation.

However, accidents with sealed sources have a much lower impact in the public perception about the risks of radiation than the accidents involving the nuclear industry. As a consequence, the pressure that the public applies to legislative and regulatory action in this field is usually weaker than that applied in the regulation of the nuclear fuel cycle, with less control and enforcement in use of radioactive sealed sources, despite the many accidents with fatalities.

There is a large amount of sealed sources under the responsibility of licensees and another large number already collected as radioactive waste and there is a risk associated to these sources that must be under regulatory control.

The analysis of the reported accidents has provided useful information on the representative times of exposure and representative individual-source distances, allowing to derive scenarios and to calculate the expected doses that were to be incurred in the events. The most general description of such accidents is an individual of the public picking up an orphaned source, unaware of the nature and risks of the shinny metallic object lying in the ground. Shortly thereafter, the individual puts the source in a pocket of her/his clothes, usually the trousers. After staying a few hours with the source close to the body, the individual brings the source to her/his home, starting the irradiation of individuals of the family.

Based on the data, three scenarios of exposure to exhumed sealed sources from the repository are devised:

1. Source in contact with the body for 5 hours;
2. Source in contact with the body for 8 hours;
3. Source at 4 meters for 24 hours;

The results provide the basis for the derivation of exposure scenarios to sealed radioactive sources disposed of in a repository in the case that they are exhumed by future earth works in the repository site. These results will be used in the calculation of safety indicators for the repository concept under development in the Department of Waste Management of IPEN. This research is intended as a contribution to the establishment of a methodology for safety analysis of SRS disposal facilities.

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