

INTEGRATED MANAGEMENT DATA SYSTEM FOR RADIOACTIVE WASTE REPOSITORIES (SGI3R) - DEVELOPMENT OF THE INVENTORY MODULE

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ABSTRACT

In Brazil, CNEN is responsible for the intermediate and final storage of radioactive waste generated in the country. The CDTN/CNEN coordinates the RBMN Project for the implementation of the National Repository for disposal radioactive waste of low- and intermediate-level. The results of this Project should be presented so that all data being easily retrievable and useful for all institutions involved, including the regulators. To achieve this goal it was developed at the Waste Management Department - SEGRE/CDTN – a management database system, called “Integrated Management System for the Management of Repository for Radioactive Waste” (SGI3R). The System consists of relational tables, forms and reports, preserving all available information, avoiding duplication of efforts, additional costs, and it will additionally give support to improve the management of RBMN Project. This paper presents a summary of this development with emphasis on the INVENTORY Module. The data from the inventory of disused sealed sources, which are stored in CDTN, were used to test the functionality of this module and of the SGI3R. These sources were categorized according to guidelines of the IAEA, and it was also presented how they should be safely managed over time.

1. INTRODUCTION

It is internationally recognized the important link among the use of nuclear energy and its applications, and promotion of welfare of mankind. The applications of radioisotopes in various fields such as medicine, industry and environment, as well as the use of nuclear energy for peaceful purposes, as a source of energy, have increased considerably in Brazil and, as in all human activities, can generate waste. According to its concentration of radionuclides, they can be classified as radioactive wastes of low–and intermediate-level, according to the standard CNEN-NE 06.05 [1], and should safely be treated, stored until its final disposal in repositories.

The Federal Law 10,308 [2] provides the requirements for site selection, construction, licensing, operation and inspection of deposits for the storage of radioactive waste in Brazil, including the repository. The responsibility for site selection, design, construction and operation is legal authority of the National Commission of Nuclear Energy (CNEN). The Center for Development of Nuclear Technology (CDTN) is one of the research institutes of the CNEN and is responsible for coordinating the implementation of the Project for the National Repository – RBMM Project. In the repository will be disposed low- and

intermediate-level waste generated by NPPs, fuel cycle facilities, research institutes and small generators, arising from the current scenario and future of nuclear power in the country, according to the Brazilian Nuclear Plan [3].

Therefore it is essential to have a system that allows effectively consolidate and manage information of different natures, to support the National Repository Project and regulators, since there are data previously generated and others that are and will be generated during the project's stages. Thus, it was developed and implemented at the Department of Waste Management (SEGRE) of CDTN / CNEN a databases manager system, called Integrated Management System for Data Repositories for Radioactive Waste (SGI3R) [4].

In this work the development of SGI3R is summarized, emphasizing the functionality of the Inventory module and its application in the management of disused radioactive sources.

2. INFORMATION SYSTEM FOR REPOSITORY

The implementation and operation of a radioactive waste repository generates a large amount of records that need an appropriate and robust system for its efficient organization and retrieval. The information about the inventory of wastes received and stored, the safety analysis reports, the administrative and operational procedures, research reports and studies, processes, environmental and radioprotection data, among other, are part of these records.

The management and control of these records are part of the Quality Management System (QMS), whose role is critical for both the maintenance of the entire plant until its closure [5], and to meet regulatory compliances.

The Information System is a tool that, in addition to support decision making, coordination and control, helps managers and employees in problem analysis, visualization of complex issues and creating new products [6].

A database is a collection of data stored and interrelated, that meets the needs of multiple users within one or more organizations. The motivations for using databases instead of files are: increased availability for a diverse set of users, data integration for easy access, updating of complex transactions and less redundancy of data. It is usually handled through a software system known as Database Manager System (DBMS). A DBMS allows a logical view (schema, subschema); physical sight (access methods, "Clustering data"); definition language and data manipulation and important utilities, such as transaction management, concurrency control, data integrity and recovery and security flaws [7].

Currently the most widely adopted data model is relational. ® Access is a relational database in which information are organized in tables. The Access ® software considers as the basis of the activities of database: objects, queries and reports. It is a tool that allows access to relational database and converts it to Structured Query Language (SQL) the various forms of input, especially the queries in Query By Example (QBE) [8].

3. DISUSED SEALED SOURCES

Sealed radioactive sources are of wide application in medicine, industry, agriculture and research centers. It is estimated that worldwide the number of these sources is of a million, although the existing records indicate much smaller amount.

Disused sealed radioactive sources (DSRS) are the subject of international concern since many of them, although are not being more used, their activities are on the order of GBq or TBq. To avoid and minimize the probability of malicious acts, the International Atomic Energy Agency (IAEA) recommends their categorization according to their properties and needs of radiological protection and safety.

2.1. Categorization for sealed sources

The Guide to Categorization of Radioactive Sealed Sources RS-G-1.9 [9] is product of the resolutions of the General Conference of 2004 [10] and of the Code of Conduct [11] and aims to promote a simple and logical system of grading radioactive sources according to their potential to cause harm to human health, grouping them by practice. It applies to sealed sources, but the methodology can also be used to radioactive open sources. It is anticipated its use by Regulatory Authorities in establishing appropriate levels of safety related control of radioactive sources existing acquired or manufactured. The basis for the categorization system of the sources are: its potential to cause harm; similar practices should stay in the same category and the establishment of the concept of "dangerous sources," i.e., a "dangerous source" without proper control can result in a exposure, causing severe deterministic effects, which can be fatal, or even result in irreversible damage, reducing the quality of life.

The concept of dangerous source with respect to its potential to cause harm to health is determined by the relation A / D , in which:

A = activity of the radioactive material contained in the source of a particular practice;

D = normalized value, established according to the specific activity of the radionuclide.

(Factor created in the context of a radiological emergency to compare risks).

The calculation of value D considers scenarios of external and internal exposure, as shown in Fig. 1.

D-values were calculated including the external exposure and internal exposure

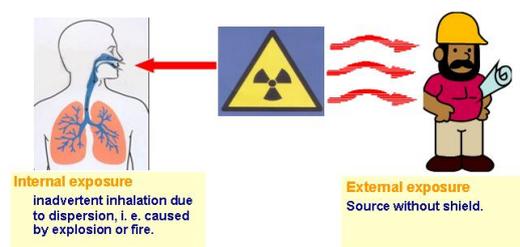


Figure 1. Exposure scenarios considered for calculating the value D [9]

In Table 1 is summarized the recommended categories according to the main practices [9]. The levels of physical security increases from category 5 to 1, i.e., sources of category 1 require a higher level of care.

Table 1. Recommended category for sealed sources for the most common practices [9]

Category	Source and Practice	Activity ratio (A/D)
1	Radioisotope thermoelectric generators (RTGs); Irradiators; Teletherapy sources; Fixed, multi-beam teletherapy (gamma knife) sources.	$A/D \geq 1000$
2	Industrial gamma radiography sources; High/medium dose rate brachytherapy sources.	$1000 > A/D \geq 10$
3	Fixed industrial gauges that incorporate high activity sources; Well logging gauges.	$10 > A/D \geq 1$
4	Low dose rate brachytherapy sources (except eye plaques and permanent implants); Industrial gauges that do not incorporate high activity sources; Bone densitometers; Static eliminators.	$1 > A/D \geq 0.01$
5	Low dose rate brachytherapy eye plaques and permanent implant sources; X ray fluorescence (XRF) devices; Electron capture devices; Mossbauer spectrometry sources; Positron emission tomography (PET) check sources.	$0.01 > A/D$ and $A > \text{Exempt}$

In the Guide RS-G-1.9, tables are presented for categorizing the sources used in practices grouped by common practice and ordered according to the radionuclide and activity. To drawing up these tables was made a detailed study, considering factors such as: shape, shield and circumstances of use of the source, as well as experiences of accidents/incidents involving radioactive sources.

4. DISUSED SEALED SOURCES (DSRS) MANAGEMENT AT CDTN

In Brazil, the disused sealed sources (DSRS) are sent to research institutes of the CNEN that has the legal authority to receive them and keep them safely under their control. In the Fig. 2 is shown the Storage Installation of Sources and Treated Wastes (DFONTE) of CDTN, a facility for interim storage of CNEN.

In general, the sources stored in CDTN come from radioactive installations that use mainly, nuclear gauges, sources of teletherapy, brachytherapy and measurement sources. Although they are considered obsolete, these sources still have the level of activity of GBq or TBq. They are stored in the DFONTE in a secure manner in order to prevent them from being stolen or damaged, preventing unauthorized use and thus minimizing the probability of incidents or accidents, as the event occurred in Goiania with a ^{137}Cs source in 1987.



Figure 2. CDTN's Storage Facility of Sources and Treated Wastes (DFONTE)

The goal of the Sources Management at CDTN is to reduce their stored volume; therefore the first option is their reuse. For this, at CDTN it was designed and built the Treatment Laboratory of Sealed Sources – LABFONTE, where they are evaluated and made available to users of radioisotopes. Within this philosophy it was introduced in the import contracts for purchase of sealed sources a return clause to the manufacturer, when they are considered out of service. Finally, a strategy that has been used for the sources that were acquired before to this clause is the repatriation, as a result of agreements between Brazil and the countries of origin [12].

Aiming the effective control of the sources and norms of CNEN, all available information about the sources stored in CDTN were included in the database SISFONTE - Information System of Disused Sealed Sources [13]. The recorded sources are also photographed in their shields in order to keep the register up to date and facilitate the identification of radionuclides, manufacturers of sources and shielding [14]. The system was developed in Access® for Windows.

5. METHODOLOGY

For the SGI3R development was followed the methodology for the implementation of a database, with application of the DBMS software, using object-oriented technology and associated with the storage steps of Radioactive Waste Management.

5.1. System modeling

Initially for system modeling, from the various aspects related to the repository, the information was grouped under eight common classes (object), which were called "module," optimizing the structure of the system. These eight (8) modules are: types of repository, technology, partners, legislation, site selection, communication, documents and inventory.

The potential users were also defined detailing the use cases and permissions, which are representations of the main functions of the system, and agents, or the definitions of the roles of agents (users who interact with the system). The user interfaces for each use case have been detailed; it was delineated the graph layout, the description of the relationships, the properties of controls and inputs and outputs of the system. After the consolidation of all these steps, it was drawn up a conceptual design and data flow diagram of SGI3R.

The assessment of the whole structure modeled was made by functional and structural tests on the system. To this, data were included in structures, and it was examined the possibility of transforming the original data in a variety of outputs such as forms, reports, labels and graphics. It was developed and implemented the database interface compatible with the Windows® platform, specific to the Repository subject. It is designed to be maintained and accessed by the system manager databases, the SGI3R in management mode (interactive operation).

In SGI3R are involved: data processing (insert, update and delete), integration, standardization and consistency between the processes that occur within and between modules. These processes correspond to use cases identified in the modeling phase, which are the users' interactions with the system.

Currently four SGI3R modules are developed: documents, repository types, site selection and inventory. For each module tables (records and fields) were created for the storage of information available, prepared the entry forms and subforms for data presentation. Standardized consultations were also created, pre-determined or by search (selection of related parameters), together with reports that describe and summarize this information.

5.2. Structure of the inventory module.

This module would process the related data for the control of the National Inventory of Radioactive Waste, such as: origin, size, type, radionuclides, and adopted classification in radioactive waste management. Because of the diversity of information on Radioactive Waste generated and stored at CDTN and other facilities it would not be possible to initiate the step of modeling with these data. So, was decided to work initially with the DSRS for checking the function of the module and SGI3R.

An important step of the elaboration of this module was to select parameters and equations that allow to represent each source in a unique way and to realize all the calculations required to establish the inventory of radioactive waste. In addition, criteria were also established, within the computer language, so that information could be consolidated, transformed and presented in the guides so clear and simple for users. These parameters and equations are linked to certain specific fields of tables which, in turn, are objects that represent information such as text, bulleted lists, buttons, check boxes and images.

Thus the main characteristics of the sources, in this module, are listed in the specific guides of the form "frmFontes": General Source/Manufacturer, Shield, Observations and Categorization (Fig. 3).

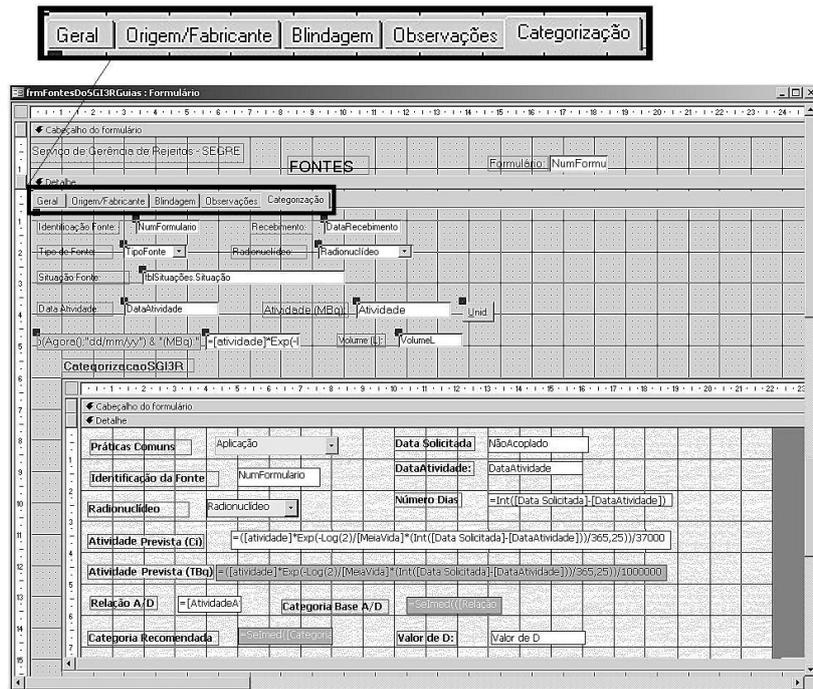


Figure 3: Screen of the Form SGI3R system, with the guide "Categorization"

On the General (Geral) tab is presented a summary of the most relevant information of the sources, such as identification, date received, type of radiation and source, its application, radionuclide, date and initial activity, dose rate, location and storage situation. In this guide was also added the expression of equation (1) for the calculation of the total activity (At) on the current date, i.e., on the date of appointment (Now), where [activity] and [DataActivity] are the initial activity and the date of manufacture and supply, respectively.

Briefly, the value of the total activity, which considers the radioactive decay as a function of initial activity, the date of the activity and half-life of the radionuclide, is automatically updated when the form of register of sources and their coupled guides are executed (activated) and is easy to see the current date.

In the Categorization tab (Categorização) it was used the strategy of recording in tables all data referring to sources and relate them, as it is shown in Fig. 3. So it is possible to see quickly and efficiently the information requested, through the controls (buttons, check boxes, etc.) linked to these tables. Basic data for the categorization of sources were incorporated, such as the total activity on a certain date, the values of D, the values computed from the A/D. The expressions for these calculations are presented, in short, by equations (2), (3) and (4).

In order to conclude the INVENTORY module, forms, reports and graphs were created, which summarize the information and make possible their presentation and printing in various ways.

$$At=(Activ:[activity]*Exp(-Log(2)/[Half-Life] *(Now()-[ActivityDate])/365,25) \quad (1)$$

$$At=(Activ:[activity]*Exp(-Log(2)/[Half-Life] *(Int=([RiqueredDate]- [ActivityDate])/365,25)) \quad (2)$$

$$A/Dcalc = At/Dtab \quad (3)$$

To compare:

$$(A/Dcalc) \text{ with } (A/Dtab) \text{ and to Categorize (Tab 1)} \quad (4)$$

6. RESULTS

SGI3R is accessible by the main form with the options for access to four modules developed, highlighted in Fig. 4. The mode of operation is through the main menu (interactive operation).



Figure 4. Screen of the main form

6.1. INVENTORY module.

Basically, the records of disused sources stored in CDTN were incorporated in this Module; these data are also part of SISFONTE. The access to the inventory data is done by the form "Inventory Sources Control" (Fig. 5), which contains the command buttons for viewing the output reports and graph.



Figure 5. Screen form of the INVENTORY Module

The total inventory of waste includes all waste generated, processed and stored. It is emphasized that the DSRS can be assigned to other users, providing that all technical and legal requirements are satisfied for this. Here the data of these sources were used to test the module SIG3R Inventory. They were grouped according to their application (practice) and radionuclide, according to the guidance of the Safety Guide RS-G-1.9 [9], as shown in Table 2. The data sources stored in CDTN were included and processed, in order to validate the parameters, criteria and calculations established for their categorization in the SGI3R. The data generated in the INVENTORY Module are useful in defining the strategy for the secure management of DSRS.

Generally the system manager specifies the tables/queries input, specifies the field names, properties of filters and sorting/grouping. To create the query (qry) and extract the data relating to the category 1 "sealed sources used in teletherapy" is executed the query, which can be saved and formatted as a form or report. From the INVENTORY module can be retrieved a lot of information about the sources stored in CDTN.

Among these sources there are 16 of teletherapy, and their categorization was made according to their total activity for the date 31/03/2011 (Table 3). Initially, 15 of ^{60}Co were classified in category 1 and one ^{137}Cs in category 2, but following the recommendation of the IAEA are all treated in the first category. From Tables 4 and 5 it is observed that the sources of teletherapy of category 1 represent about 97% of the total activity, thus requiring special care in storage, because they are considered "dangerous sources", according the categorization system [9]. Therefore security measures for these sources in the intermediate storage must be taken considering their possible risks.

Table 2. Inventory of Stored Sources of Radionuclide (31/03/11)

Radionuclide	Amount of DSRS	Total Activity (TBq) on 31/03/11
²⁴¹ Am-Be	7	0.017
⁶⁰ Co	229	118.337
¹³⁷ Cs	1030	64.580
⁸⁵ Kr	40	0.144
²²⁶ Ra	407	0.062
⁹⁰ Sr	44	0.012
Outros (²⁴¹ Am, ¹⁴ C, ¹⁴⁷ Pm, ⁵⁵ Fe, ²⁵² Cf, etc.)	39	0.109
Total	1796	183.261

Table 3. Inventory and category of teletherapy sources stored in CDTN on 03/31/2011

Radionuclide	⁶⁰ Co	¹³⁷ Cs
Total Activity (TBq)	1.18E+02	5.88E-01
Ratio of A/D _{calc}	4.00E+03	5.29E+02
Category		
Based A/D _{calc}	1	2
Recommended	1	1

The tab "Categorization" (Fig. 6) presents the category of one of the sources of ⁶⁰Co that was calculated from the total activity on 03.31.2011 (established date) and the values of D, resulting in a calculated A/D ratio, and this is compared with the values A/D tabulated [9]. It is also indicated the required volume to store the source shield.

In this guide it is possible to simulate, in a certain future date, to which category belongs a specific source. An example of this is presented in Figure 6, where it is displayed, in detail, the categorization of this source of cobalt on the date of 31.03.2080, showing that, on this occasion, it will belong to category 5, with a much lower risk level than on 31.03.2011, category 1.

Therefore, using the equations for categorization of the sources it can predict the security measures that each source needs, over time, and the volume will be occupied by each category of sources, in order to prepare the intermediate storage and, in case of repatriation, how they should be segregated, according to the security requirements for shipping.

In addition, data of the waste stored at CDTN can be directly extracted from this Module as a report and given to the regulators with the updated information.

frmFontes

Serviço de Gerência de Rejeitos - SEGRE

FONTES Formulário: FR00179

Identificação Fonte: FR00179 Recebimento: 24/8/1995

Tipo de Fonte: Selada Radionuclídeo: Co60

Situação Fonte: Armazenamento Intermediário - Prédio 33

Data Atividade: 10/9/1976 Atividade (MBq): 1,53E+08 Unid.

Atividade em 11/04/11 (MBq): 1,62E+06 Volume (L): 200

Categorização SGI3R

Práticas Comuns: Teleterapia Data Solicitada: 31/3/2011

Identificação da Fonte: FR00179 Data Atividade: 10/9/1976

Radionuclídeo: Co60 Número Dias: 12620

Atividade Prevista (Ci): 4,40E+01 Atividade Prevista (TBq): 1,63E+00

Relação A/D: 5,42E+01 Categoria Base A/D: 2

Categoria Recomendada: 1 Valor de D: 0,03

Registro: 179 de 1796

Detalhe da Guia de 31/1/2080

Práticas Comuns: Teleterapia Data Solicitada: 31/1/2080

Identificação da Fonte: FR00179 Data Atividade: 10/9/1976

Radionuclídeo: Co60 Número Dias: 37763

Atividade Prevista (Ci): 5,14E-03 Atividade Prevista (TBq): 1,90E-04

Relação A/D: 6,34E-03 Categoria Base A/D: 5

Categoria Recomendada: 5 Valor de D: 0,03

Figure 6: Screen form of the tab "Categorization" filled with data from a source of ^{60}Co teletherapy on 31.03.2011 and 31.03.2080

CONCLUSIONS

The creation and development of the Integrated Management System for Radioactive Waste Repositories (SGI3R) aims the consolidation of all the important information regarding the repository. Thus the use of SGI3R will enable the effective control of its data, also allowing all data are consolidated, sorted, easily retrievable and useful for all stakeholders.

The System was developed based on relational tables, forms and reports documented, to optimize the steps in the Repository Project (RBMN), preserving all information, so that it becomes available, avoiding duplication of efforts and additional costs, supporting the planning and control of the RBMN, now and in the future.

The SGI3R consists of eight modules; four of them are already developed. The Inventory module with the information about the sealed sources stored at CDTN gives support to the evaluation and selection of security measures for their effective management, in accord to each category, at any time. Thus it is important to highlight the updating of total activity and, consequently, of the sources categorization, because in this way their storage, handling, transport and deposition can be planned, avoiding an unnecessary increase in costs relating to the safety of these steps.

It is important to highlight the importance of the total activity updating and, consequently, of the sources categorization, because can be planned their storage, handling, transport and deposition, avoiding an unnecessary increase in costs relating to the safety of these steps.

Finally, the system will allow transparency in the process of study and implementation of the National Repository.

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