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Occupational monitoring at radioactive waste deposit

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ABSTRACT

The Initial Deposit of Low Activity Radioactive Waste - DIRBA is an ancillary facility to the Nuclear Fuel Factory - FCN for the initial storage of low activity radioactive waste generated in the nuclear fuel cycle under the responsibility of the FCN. Currently approximately 460 200-liter drums containing Class 2.3 waste are stored: Waste containing Natural Radionuclides (RBMN-RN). As part of the nuclear licensing of the facility, an area radiological monitoring program was developed with monthly monitoring of 17 exposure points, 3 direct long-distance air sampling points with CAM alpha-7 monitors, monitored in January and 9 points where smears of alpha long half-life emitters were monitored in January. The mean exposure rate between points was 0.5 $\mu Sv \cdot h^{-1}$, with a maximum of 1.27 $\mu Sv \cdot h^{-1}$ varying, on average, between 0.98 $\mu Sv \cdot h^{-1}$ at point P1 to 0.23 $\mu Sv \cdot h^{-1}$ at P11. The monthly average was the same, 0.50 $\mu Sv \cdot h^{-1}$, ranging from 0.46 $\mu Sv \cdot h^{-1}$ (November) to 0.57 $\mu Sv \cdot h^{-1}$ (August). The half-life long-lived alpha sampling were all below the MDA as well as the 9 smears. In relation to the area monitoring requirements, expressed in the Brazilian radioprotection regulations, the deposit should be considered as a supervised area. The possibility of tipping the drums or other accidents with spillage of material contained into them caused, in a proactive way, the area to be considered a controlled area.

Key words: radioprotection, optimization, dose rate, low activity radioactive waste and waste deposit.

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1. INTRODUCTION

The Initial Deposit of Low Activity Radioactive Waste (DIRBA, Portuguese acronym) is an installation of the nuclear fuel cycle responsible for the initial storage of radioactive waste generated at the Nuclear Fuel Industry of the Nuclear Industries of Brazil - FCN/INB. It is located in Resende, state of Rio de Janeiro and is in the process of nuclear and environmental licensing.

The deposition of wastes in the DIRBA depends on some considerations: only waste produced in the process of the Nuclear Fuel Plant can be deposited. The wastes must be of class 2.3 [1]. The wastes must be put into 200 l drums and these drums may not exceed 200 kg. Drums must be identified. For deposition, in addition to the description of the contents, the drum shall have undergone surface monitoring and be free from surface contamination and shall have recorded the exposure rates on the surface and at one meter.

It is authorized to initially store Class 2.3 waste, that is Natural Radionuclide (RBMN-RN) waste by Norm CNEN-NN-8.01, and defined as: wastes containing natural or industrialized mineral raw materials containing radionuclides from the uranium and thorium series in concentrations of activity or activities above the dispensing levels established in the norm [1].

Every nuclear installation must have a license in the nuclear area, from the National Nuclear Energy Commission (CNEN) and an environmental one from IBAMA (the Ministry of Environment). Nuclear licensing is based on Norm CNEN-NE-1.04 [2], waste deposit licensing based on Norm CNEN-NN-8.02 [3], characterization of radioactivity waste based on Norm CNEN-NN-8.01 [1], and transportation of radioactive material based on Norm CNEN-NE-5.01 [4]. Physical security (against theft or loss of nuclear material) is based on Norm CNEN-NE-2.01 [5], fire safety on Norm CNEN-NE-2.03 [6], nuclear material control on Norm CNEN-NE 2.02 [7] and the radioactive licensing on Norm CNEN-NN-6.02 [8].

The environmental licensing of radioactive facilities was foreseen by the CONAMA (the National Council for the Environment) resolution nº 237/1997 [9], only in cases of major environmental impacts. In 2011, with the publication of complementary law nº 140/2011 [10], the criterion of significance of the impact for the licensing was withdrawn. The environmental licensing criteria were finally defined in February 2016, with Normative Instruction nº 001/2016 [11].

In the nuclear licensing of facilities several requirements must be obeyed, among them the occupational monitoring of the facility. This article aims to describe the area monitoring program of the DIRBA, part of the installation's Occupational Monitoring Program. This monitoring served as a basis for the risk classification of the facility and for the classification of areas from the radiological point of view.

2. MATERIALS AND METHODS

At DIRBA, waste-containing only 200 L steel drums are deposited in metal cages with three floors, each floor with capacity to hold a pallet with four drums onto it, see Figure 1. The use of 200 L steel drums, with a lid attached by a metal strap, associated with a monitoring of removable contamination, which only allows entry into the DIRBA of uncontaminated drums, reduces the chance of external contamination, generating focus on the exposure of workers to gamma radiation emitted by radioactive waste contained in the drums. This arrangement works with engineering control (use of sealed 200 L drums) that, associated with operational controls (mainly access control), acting together put DIRBA in line with the most modern operational standards recommended for control and classification area of radioprotection by IAEA and ICRP [12-17].

The engineering and operational controls were designed to reduce the risks of surface contamination of the drums deposited at DIRBA and, consequently, contamination and inhalation of radionuclides by employees.

Therefore, the area occupational monitoring program [12-15] focused primarily on exposure risks [16], conducting a preliminary assessment of air contamination and surface contamination.

> Monitoring should be carried out in areas that are suspected to be contaminated with long-lived radionuclides. The objective of such monitoring is to provide inputs into decisions on whether intervention is justified and whether further monitoring is necessary. If the results show that, according to the intervention levels and action levels established by national authorities, remedial actions may be required, adequate monitoring should be carried out to help establish the appropriate actions. Monitoring should also be carried out during and after the taking of remedial actions to assess their effectiveness [16].

Figure 1: *Internal view of Deposit of Low Activity Radioactive Waste - DIRBA*

The program was executed in the year 2016, and was composed of exposure rate monitoring (μSv·h^{-1}) [12, 13, 15, 16], air sampling for long half-life alpha emitters (LHLAE) in Bq·m^{-3}, [17, 18] and surface smear for LHLAE in Bq·cm^{-2} [15, 17, 18].

2.1. Exposure Rate Monitoring

The exposure rate was measured at 17 points, 15 inside the facility and two in the external area of access to the DIRBA (On the doorstep). The dose rate investigation level is fixed at 10 μSv·h^{-1} and the action level at 1 mSv·h^{-1} (1000 μSv·h^{-1}). Monthly samplings were performed for this monitoring. Monitoring was performed with Canberra Radiation Monitor 2,000, see Figure 2, with the following characteristics:

- Detector – Geiger Mueller energy compensated;
- Measurement range – 0.01 μSv·h^{-1} to 100 mSv·h^{-1};
- IEC approved measurement range – 0.3 μSv·h^{-1} to 100 mSv·h^{-1};
- Energy range (IEC 60846) – 40 keV to 1.5 MeV;
- Sensitivity – 0.83 c/s per μSv·h^{-1}; and
- Accuracy – ± 15%.

Figure 2: *Canberra Radiation Monitor 2000*

2.2. Monitoring the air concentration of long-lived alpha emitters

Air sampling was performed with the Continuous Air Monitor (CAM) Alpha-7 in January 2016, see figure 3. The investigation and action levels were 0.2 Bq·m^{-3} and 6.0 Bq·m^{-3} respectively. The main features of the monitor are:

- Detector – 490 mm^2 active area;
- Efficiency – ^{239}Pu 27% in 4π geometry; and
- Sample rate – 14 - 60 liter per minute (lpm).

Figure 3: *Alpha -7 Continuous Air Monitor*

2.3. Surface Contamination Sampling

The smear sampling was performed in January 2016, with cellulose acetate filters performing a smear in an area corresponding to 100 cm^2 and subsequent total alpha radiometry in a proportional counter model LB 770 10-channel α-β Low-Level Counter, see Figure 4. The investigation and action levels level were both 0.3 $Bq \cdot cm^{-2}$. The main features of the LB-770 are:

- Detectors – Suited to measure Ø 50 mm samples, guard counter in anticoincidence;
- Lead shield – 10 cm, 4π shield to reduce ambient radiation;
- Preamplifiers – Alpha beta separation, based on rise time & pulse height discrimination; and
- Counting gas – Argon-Methane, Argon-CO_2.

Figure 4: *LB770 10 channel low-level conter*

3. RESULTS AND DISCUSSION

3.1. Exposure Rate

The monitored dose rates for the year 2016 are reported in Table 1. The mean exposure rate was 0.5 μSv·h^{-1}, with a maximum of 1.4 and a minimum of 0.14 μSv·h^{-1}. The mean values per point appear in Figure 5 and the monthly averages in Figure 6.

3.2. Air monitoring

Air sampling resulted in values below the Minimum Detectable Activity (MDA), as shown in Table 2, pointing out the inexistence of radionuclides dispersed in the air, a condition consistent with the installation, which sources free from surface contamination as established from smear monitoring.

Table 1: Dose rates in the DIRBA in the year 2016

	Dose rate, in μSv·h^{-1}												Mean	St. Dev.
Point	**Jan.**	**Feb.**	**Mar.**	**Apr.**	**Mai**	**Jun.**	**Jul.**	**Aug.**	**Sept.**	**Oct.**	**Nov.**	**Dec.**		
p1	0.96	1.00	0.95	1.08	1.12	1.27	0.86	0.99	0.97	0.87	0.78	0.86	0.98	0.13
p2	0.67	0.68	0.72	0.70	0.67	0.71	0.25	0.58	0.60	0.69	0.59	0.62	0.62	0.13
p3	0.68	0.65	0.70	0.72	0.65	0.63	0.48	0.72	0.53	0.57	0.66	0.49	0.62	0.09
p4	0.51	0.56	0.40	0.60	0.49	0.93	0.68	0.76	0.60	1.26	1.01	0.89	0.72	0.25
p5	0.74	0.90	0.80	0.84	0.66	0.57	1.27	0.90	0.92	1.03	0.88	1.02	0.88	0.18
p6	0.53	0.60	0.62	0.62	0.91	0.85	0.62	0.87	0.75	0.67	0.61	0.70	0.70	0.12
p7	0.60	1.40	0.70	0.76	0.81	0.71	0.73	0.90	0.92	0.50	0.62	0.78	0.79	0.23
p8	0.32	0.27	0.31	0.25	0.71	0.47	0.54	0.60	0.45	0.51	0.60	0.51	0.46	0.15
p9	0.42	0.32	0.37	0.34	0.44	0.40	0.52	0.72	0.66	0.67	0.58	0.63	0.51	0.14
p10	0.44	0.33	0.42	0.38	0.36	0.54	0.55	0.45	0.52	0.33	0.25	0.20	0.40	0.11
p11	0.25	0.21	0.32	0.35	0.17	0.14	0.17	0.37	0.22	0.20	0.16	0.20	0.23	0.08
p12	0.25	0.36	0.24	0.29	0.17	0.18	0.27	0.30	0.36	0.18	0.20	0.18	0.25	0.07
p13	0.20	0.29	0.18	0.21	0.47	0.35	0.25	0.20	0.19	0.25	0.18	0.18	0.25	0.09
p14	0.52	0.68	0.55	0.60	0.19	0.22	0.57	0.36	0.33	0.25	0.17	0.20	0.39	0.19
p15	0.26	0.23	0.30	0.33	0.17	0.17	0.28	0.30	0.25	0.18	0.17	0.20	0.24	0.06
p16	0.22	0.24	0.20	0.20	0.38	0.25	0.37	0.19	0.25	0.15	0.18	0.21	0.24	0.07
p17	0.25	0.21	0.22	0.24	0.27	0.38	0.36	0.40	0.31	0.15	0.18	0.20	0.26	0.08
Mean	0.46	0.53	0.47	0.50	0.51	0.52	0.52	0.57	0.52	0.50	0.46	0.47		
St. Dev.	0.22	0.34	0.24	0.26	0.28	0.31	0.27	0.26	0.26	0.33	0.29	0.30		
												Mean (general)	0.50	
												St. Dev. (general)	0.28	

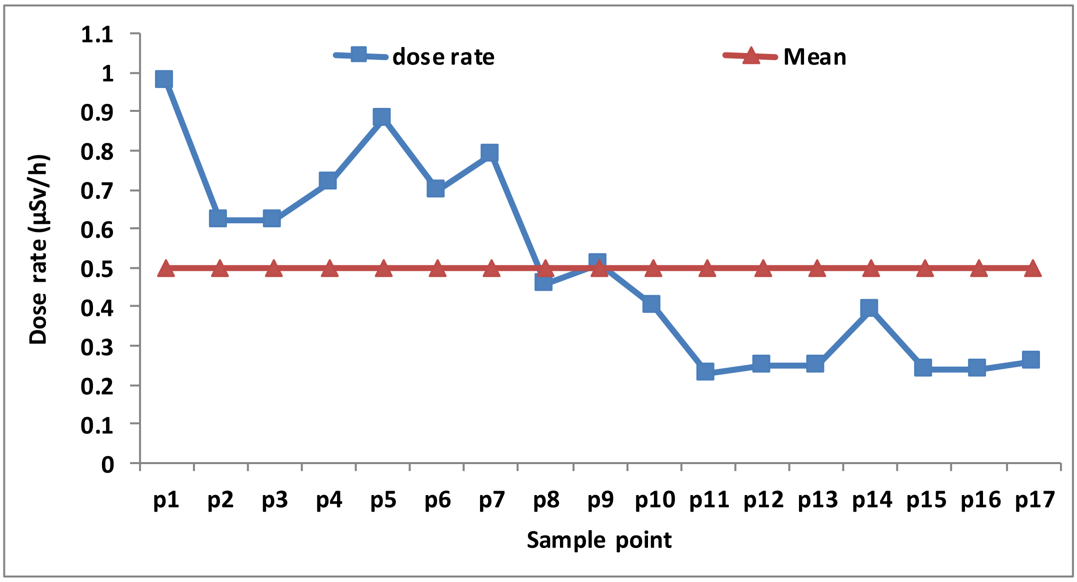

Figure 5: *Annual mean values of exposure rates, per point*

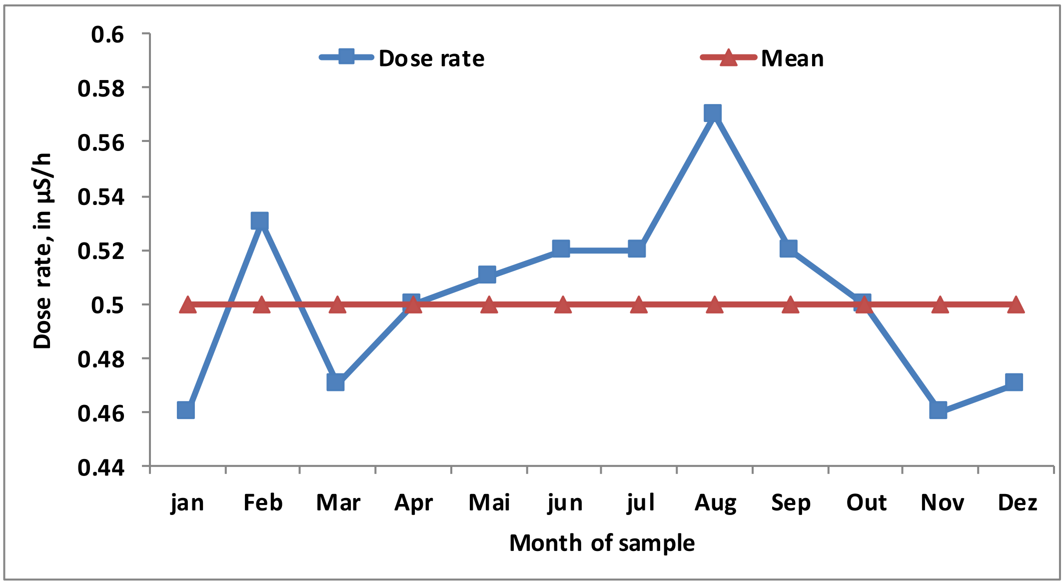

Figure 6: *Mean values of exposure rates, per month*

3.3. Surface contamination sampling

The monitoring of surface contamination showed values below the MDA, see Table 3. This again is compatible with the characteristics of the facility that operates sealed sources. In such cases, surface contamination by radioactive materials not expected.

Table 2: Air sampling with CAM Alpha-7

Point	Concentration of LHLAE* ($Bq \cdot m^{-3}$)	MDA** ($Bq \cdot m^{-3}$)	Flow rate (m^{-3})
PA1	< MDA	0.0493	7.392
PA2	< MDA	0.0466	6.341
External area	< MDA	0.0320	7.453

*LHLAE – long half-life alpha emitters and **MDA –minimum detectable activity

Table 3: Smear sampling and description of sampling points, in $Bq \cdot cm^{-2}$

Sample	Value ($Bq \cdot cm^{-2}$)
ESF-01	< 0.01
ESF-02	< 0.01
ESF-03	< 0.01
ESF-04	< 0.01
ESF-05	< 0.01
ESF-06	< 0.01
ESF-07	< 0.01
ESF-08	< 0.01
ESF-09	< 0.01

4. CONCLUSION

To assist in the operationalization of radioprotection, the ICRP [20] classifies two the types of areas controlled areas and supervised areas.

1. A controlled area is a defined area in which specific protection measures and safety provisions are, or could be, required for controlling normal exposures or preventing the spread of contamination during normal working conditions, and preventing or limiting the extent of potential exposures; and
2. A supervised area is one in which the working conditions are kept under review but special procedures are not normally needed. A controlled area is often within a supervised area, but need not be.

Areas that do not fit in these classifications can be considered as areas free of radiological control (free areas).

The deposition way of waste-containing drums shows a low risk of contamination. The results of the sampling of air contamination by LHLAE (less than 0.05 $Bq \cdot m^{-3}$ compared to an investigation level of 0.2 Bq·m^{-3}) and surface contamination (less than 0.01 Bq·cm^{-2} compared to a level of investigation of 0.3 Bq·cm^{-2}) point to negligible risks of contamination, corroborating the initial premise.

The exposure rate remained within the limit for the public individual's exposure rate (0.5 μSv·h^{-1}). Since it is not planned to work constantly in the DIRBA, but rather to occur sporadic motivated and authorized entries, the DIRBA could be classified as ‘free area’.

In the risk assessment of DIRBA, the possibility of falling of the drums and consequently the spilling of their contents, generating the possibility of contamination was taken into consideration. This evaluation associated with the mean value of limit dose rate caused the area to be defined as ‘controlled area’.

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