

Decommissioning an Uranium and Thorium Facility: *A Radiation Protection Approach*

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Abstract. Decommissioning means actions taken at the end of the useful life of a facility in retiring it from service with adequate regard for the health and safety of workers and members of the public. In the present work, we introduce a radiation protection approach for the removal of radioactive material to the extent that the facility or site becomes available for use without restriction. The facility to be decommissioned is a fuel cycle pilot plant that operated with natural uranium and thorium for almost two decades and then, kept inactive for about 10 years at the Nuclear and Energy Research Institute - IPEN. Even after this long period of inactivity, it has presented significant levels of radiation and contamination spread over the floor, walls, windows, doors and ceiling. The fuel cycle pilot plant was completely dismantled, remaining only the walls and the concrete structures. In this work we present the job done to restore the area. According to each step of dismantling a continuous monitoring of the contaminated surfaces was carried out including the survey of the deep material from the floor and walls. The material identified as radioactive waste was stored into appropriated metal drums. A radiation protection team guided this stage of the work, prescribing the tasks, and the amount of material that should be removed from floors, windows and ceiling. For this, repetitive surveys had to be done. The results of monitoring and contamination levels were analysed, thus guiding the next steps of the job. In this way radiation protection team took over the tasks, running the work with the purpose of achieving acceptable levels of radiation, restoring the area for unrestricted use.

KEYWORDS: *contamination; decommissioning; decontamination; radiation protection; nuclear facility.*

1. Introduction

For a nuclear facility, decommissioning is the last phase of its life-cycle. Usually nuclear facilities are specially designed building, constructed and licensed for the handling of radioactive and nuclear material. In this case, a facility was adapted and prepared for handling nuclear materials related to the fuel-cycle, having been operated for years. However, political and administrative changes led to closing of the facility, and consequently the necessity of decommissioning the building for others purposes, not involving the handling of nuclear and radioactive material. The facility to be decommissioned is a fuel cycle pilot plant that operated with natural uranium and thorium for almost two decades and then, kept inactive for about 10 years at Nuclear and Energy Research Institute - IPEN. Even after such a long period of inactivity, significant levels of radiation have been found, with contamination widely dispersed on floors, walls, windows, doors and the ceiling. In this way, decommissioning actions were taken with adequate regard for the health and safety of workers and members of the public. It is usual to divide these actions into three stages [1]:

- Stage I – To close down the facility, with a minimum removal of radioactive material and with continuous surveillance,
- Stage II – Decontamination to acceptable levels of radiation. Removal of radioactive material to the extent that the restricted site releases,
- Stage III – Removal of radioactive material to the extent that the facility or the site becomes available for use without restriction.

In the present work, we introduce a radiation protection approach for the last stage, i.e. the stage III of decommissioning program. The previous stage including the removal of radioactive materials and equipments took place in an earlier action. This work aims to present the main activities carried out to restore the area for further free of radiation use.

2. Decommissioning Stage III

According to the safety standards issued by the Brazilian regulatory authority [2,3], and on the recommendations of the International Atomic Energy Agency - IAEA, for the decommissioning of nuclear facilities [1, 4] it was developed a plan for the dismantling and decontamination of this old uranium and thorium pilot plant, Fig.1. The unit processed uranium to produce nuclearly pure uranium nitrate. Lately a thorium unit was assembled to obtain chemically pure thorium nitrate. This pilot plant was part of the several fuel cycle facilities of IPEN.

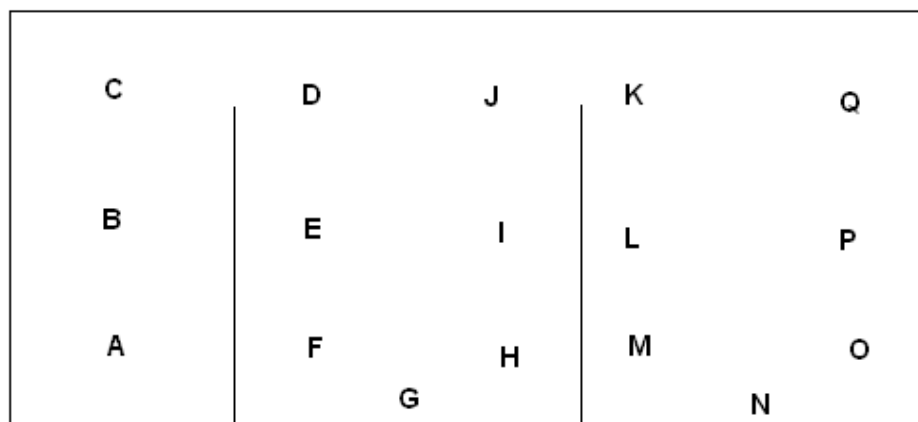
Figure 1: Uranium and thorium pilot plant at IPEN.



The plant was located at the floor level of a building and embodies three rooms contiguously, linked by a corridor, Fig 2. In the left side of the plant, there was a chemical reactor for preparation of thorium oxycarbonate (point C), and also the washing columns (points A and B) and related pipelines. At the central room there was an industrial fume hood for weighting uranium and thorium (points E and F), and also several chemical reactors, tanks and filter systems for uranium processing (points H, I and J). In the right room there was the control panel (points K and Q) and a pulsed column for uranium extraction with solvent (points L and M). At the points P and O there was a chemical reactor for uranium and thorium waste precipitation.

The unit contained several machines and equipments like, chemical reactors, metallic structures, pipelines, pipe racks, pipe bombs, tanks among to theirs components, it was one of the first buildings to be decommissioned at IPEN.

Figure 2: Uranium and thorium facility monitoring points



**URANIUM AND THORIUM FACILITY
MONITORING POINTS**

As a first step in the development of a radiation protection programme the identification of situation involving occupational exposure was the priority. Therefore, the radiation protection team made the radiological and chemical inventory of the material, as well as the identification of the contaminant radionuclides of the area. Thus, the radiological survey of the pilot plant was carried out, taking into account both normal and potential exposure.

A radiation protection programme was devised to guide the activities of dismantling, decontamination and waste management tasks. Initially, the assignments of responsibilities for occupational radiation protection and safety to different management levels were established. The designation of controlled or supervised areas and the local rules for workers to follow as well as the system for recording and reporting all the relevant information related to the control of exposures was implemented.

Individual monitoring for external radiation exposure were issued with thermoluminescent dosimeters and urinalysis for the assessment of internal contamination. The internal monitoring was performed before and after the tasks to evaluate the intake. A training program was implemented for the workers involved in these tasks. This program included intensive lectures on the operational radiation protection and the appropriate use of personal protective equipments.

3. Decontamination Tasks

As mentioned before, this work will focus on the decommissioning actions of Stage III. At this stage, most of the chemical reactors, metallic structures, pipelines, tanks and other machinery related equipments have already been removed. Then, the main tasks were related to the decontamination of the floor, ceiling, walls, windows and doors. Initial monitoring indicated higher than expected contamination level of the floor, walls, furnishings and equipments of the plant. The area and surface direct monitoring was carried out with G-M detectors, Fig. 3.

Figure 3: Monitoring of surface contamination.



The decontamination procedure for small equipments and furnishings was made in liquid solution of sodium carbonate for Th and citric acid for U. Large materials have been cut off by the plant operational workers to reduce the size in order to fit in the decontamination tanks.

The activities for the building decontamination consisted on the mechanical removal of ceramic pavement and also the mortar of the brick walls, Fig. 3. The major radiological problem in this step was the possibility of the widespread surface contamination to disperse in the air. In this sense, all the workers and masons was wearing total personal protection equipments. To prevent the dispersion of uranium in the air the decontamination procedure of the floor was made using water and a solution of detergent, Fig. 3.

For this purpose, a team composed by an engineer and several masons, worked in the contaminated area. This demanded a step-by-step attendance by the radiation protection team.

Figure 3: Decontamination tasks on the wall and humid method for the floor.



3.1. Shield on the Floor

After the complete removal of the radioactive material and equipments from the pilot plant, the area monitoring still indicated relatively high levels of radiation and hot spots of contamination on the floor. Although all efforts were done to remove the whole floor contamination, it was realized that the cost-benefit relationship was very high. Large amounts of floor and concrete have been removed, and the dose was still high. Another problem was the generation of radioactive waste. More than thirty drums of waste had been collected. Then, it was decided to stop the process of floor removing, and all efforts were concentrated on the hot spots. Later, it was decided to use a mix of concrete and barite as a shield in order to diminish the radiation level arising from surface contamination. For such purpose an appropriate thickness of 10 cm shield layer, with composition of 3 cm of barium sulfate (Ba_2SO_4) and 7 cm of concrete, was placed over the floor.

3.2. Personal Protective Equipment

As seen in Fig. 3, during the decontaminating activities, all the workers was wearing personal protective equipment (PPE) as: protective overalls, rubber gloves, boots and plastic cap. Besides, additional PPE were required in accordance with the developed tasks and related risks, such as dust masks, adequate filter masks, safety goggles, additional gloves and plasticized paper overalls.

3.3. Radioactive Waste Management

The natures of the waste generated at the decontamination process are solids and liquids. The solid waste, like pieces of old floor, mortar and concrete was conditioned in 50 L drums. The usual activities developed in the pilot plant resulted in low-level radioactive solid waste like, wore-out gloves, rubber, scraps, pieces of cotton and paper impregnated with natural uranium which was disposed in a paper bag protected by another plastic bag. These wastes were collected, registered, reported and dispatched to the waste management department of the Institute. The generated liquid waste was collected in plastic vessels. A small sample from each vessel was collected and analyzed before disposal. The generated liquid waste was accounted for the source terms to be used in the environmental impact analysis.

4. Monitoring Results

According to each dismantling step a continuous monitoring of the contaminated surfaces was carried out including the survey of the deep material from the floor and walls. The results of monitoring were analyzed, thus guiding the next steps of the job. The radiation level for direct surface monitoring was

taken at 0.7 m from the floor and the results are shown on Table 1, before and after the decontamination process. The monitoring points are shown in Fig. 1. As seen in Table 1, the monitoring points A and B, are the place where the washing columns was installed and present the major dose rate before the decontamination. These and the others points have presented much lower radiation levels after the removal of the floor and the application of the barite concrete shielding layer.

Table 1: Radiation level from area monitoring before and after decontamination process

Monitoring points	Measurement before decontamination ($\mu\text{Sv}\cdot\text{h}^{-1}$)	Measurement after decontamination ($\mu\text{Sv}\cdot\text{h}^{-1}$)
A	2.50 ± 0.05	0.30 ± 0.05
B	2.10 ± 0.05	0.25 ± 0.05
C	1.30 ± 0.05	0.25 ± 0.05
D	0.90 ± 0.05	0.20 ± 0.05
E	1.20 ± 0.05	0.20 ± 0.05
F	1.40 ± 0.05	0.20 ± 0.05
G	1.30 ± 0.05	0.25 ± 0.05
H	1.30 ± 0.05	0.25 ± 0.05
I	2.00 ± 0.05	0.30 ± 0.05
J	1.00 ± 0.05	0.25 ± 0.05
K	1.00 ± 0.05	0.25 ± 0.05
L	0.60 ± 0.05	0.20 ± 0.05
M	1.00 ± 0.05	0.20 ± 0.05
N	0.65 ± 0.05	0.20 ± 0.05
O	0.60 ± 0.05	0.20 ± 0.05
P	0.70 ± 0.05	0.20 ± 0.05
Q	0.80 ± 0.05	0.20 ± 0.05

Obs.: Radiation levels taken at 0.7 m from the floor

The external individual monitoring data for all workers have resulted in dose below the TLD dosimeter detection limit of 0.20 mSv. The internal monitoring of the workers by urinalysis is presented in Table 2. All the results of measurements by fluorimetry method have shown below the detection limit of 1.0 $\mu\text{gU/L}$. These results are in accordance with the safety procedures adopted during the removal of the floor contamination.

Table 2: Urine Analyses for Uranium, before and after the decontamination tasks

URINE ANALYSIS FOR URANIUM		
Worker	Before decontamination	After decontamination
Operator A	< DL	< DL
Operator B	< DL	< DL
Operator C	< DL	< DL
Operator D	< DL	< DL
Operator E	< DL	< DL
Operator F	< DL	< DL
Operator G	< DL	< DL
Operator H	< DL	< DL
Operator I	< DL	< DL

Obs.: <DL means lower than Detection Limit of 1.0 $\mu\text{g U/L}$. Method used: Fluorimetry

5. Conclusions

Dismantling, decontamination and decommissioning are issues that will become even more frequent. Learning with small and less complex facilities is useful when larger units must be decommissioned. Along the decommissioning activities, reports of incidents have not been noticed and the total dose received by each worker was below the register limit. These results points that a good planning and training are significant and they must be serious'ly appreciated before the beginning of a decommissioning task. In this way, the radiation protection team has contributed in achieving acceptable levels of radiation and restoring the area for unrestricted use.

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