**Continuing Education in Radiation Protection in the Nuclear Fuel Cycle. *The Case of Nuclear Industries of Brazil Education and***

***training in the uranium production cycle***

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**Abstract.** This paper describes the pedagogical and technical concept that guided training in radiation protection implemented by the Indústrias Nucleares do Brasil (INB) to maintain the competence of its technical staff to perform activities with exposure to radiation, the staff responsible for the supervision of this work and as a form of dissemination of knowledge to the staff not involved in the use of ionizing radiation. The groups of workers to be trained are here described, as well as the level of training, the frequency and types of training, the profile of trainers, the training programs, the forms of assessment and recording of training. It also describes the first general training performed in 2004. After this initial training no other general training was realized, and the option was to train small groups of workers, to avoid stopping the production as it occurred when general training was executed. The overall training was conducted in three units: the Uranium Concentration Unit (URA) under production in the city of Caetité, state of Bahia, the Ore Treatment Unit (UTM) undergoing decommissioning at Poços de Caldas, state of Minas Gerais and the Unit of Heavy Minerals (UMP), at Buena, state of Rio de Janeiro. In the initial training at URA 79 workers were trained, distributed in 6 classes (average of 13 students per class); each class had nine hours training and the grades obtained ranged from 7.5 to 10. At UTM, 200 employees were trained distributed in 9 classes (average of 22 students per class); their notes ranged from 8.8 to 10. Finally, at UMP 151 employees were trained, in 5 classes (average of 31 students per class); their grades ranged from 8.6 to 9.0. That year, a total of 180 hours were spent for training 430 employees, with no effective rebuke. Currently employees are trained when they arrive at their Units, and all along the year in small classes, as the general training has been definitely abolished.

**1. Introduction**

The activities in the nuclear fuel cycle require a continuous program of training and human resource development. The International Atomic Energy Agency (IAEA), possess several recommendations for the training [1, 2, 3]. In the same vein, another recommendation on occupational doses appraisal [1], points out the training as a way to reduce the doses to which workers are exposed. The IAEA [4, 5] also points out training as a fundamental key in radioprotection that results in optimization of the doses received by the worker. Similarly, in other areas that work with radioactive sources, training and also predominant focus [6].

In Brazil, only the “Indústrias Nucleares do Brasil - S.A” (INB) operate the nuclear fuel cycle. Being a small market restricted to a single company, the required technical training is only performed by the National Commission of Nuclear Energy (CNEN) or by the INB itself.

Aware of their responsibilities with regard to the safety of workers and the population, INB initiated an effort of internal training of human resources and training of workers in radiation safety, based on a training program. This training program is a requirement of national standards for radiation protection [7, 8].

|  |  |  |
| --- | --- | --- |
|  | **Directory of Ore Resources** |  |
|  |  |
|  | **Radioprotection Service** |  |
|  |  |
|  |
|  | **Employees of the****Radioprotection Service** |  | **Other employees** |  |
|  |  |
|  |  |  |
|  |
|  | **Managerial Level: 8h/semester** |  | **Managerial Level: 8h/semester** |  |
|  |  |
|  |
|  | **Higher Level:****16h/semester** |  | **Higher Level:****16h/semester** |  |
|  |  |
|  |  |  |
|  | **Technical Level:** **8h/semester** |  | **Technical Level:** **8h/semester** |  |
|  |  |
|  |
|  | **Elementary Level:** **8h/semester** |  | **Elementary Level:** **8h/semester** |  |
|  |  |
|  |

***FIG. 1*** – Classification of employees from DRM depending on hierarchical level and workplace and academic formation used in the training and their respective frequencies.

**2. Objectives**

The conceptions that oriented the training procedures in radioprotection of the employees of INB are here described.

**3. Methodology**

***3.1.Training place***

The overall training was conducted in three units: the Uranium Concentration Unit (URA) under production in the city of Caetité, state of Bahia, the Ore Treatment Unit (UTM) undergoing decommissioning at Poços de Caldas, state of Minas Gerais and the Unit of Heavy Minerals (UMP), at Buena, state of Rio de Janeiro.

***3.2. Distribution of the employees in homogeneous groups for training***

The employees were distributed in two groups: those that belong to the Radioprotection Service and the other employees, as can be seen in Fig 1.

***3.3. Level of training to be developed***

Three levels of training were considered: a) to acquire competence; b) to maintain competence and c) to broaden competence.

***3.4. Kinds of training to be developed***

*3.4.1. Theory Classes*

The theory classes should provide the theoretical background needed for the development of other forms of training. When possible, should be accompanied by practices whose workload has different score, such that each two hours of practice should be equivalent to one hour of theory.

*3.4.2. Practical Classes*

The practical classes should provide sedimentation of knowledge acquired in classes of theory, and as far as possible, bring new information.

*3.4.3. Lectures*

Lectures should deepen theoretical and/or practical issues, with a maximum time of 2 hours.

*3.4.4. Internal Workshop*

Internal workshopshould deepen theoretical and/or practical issues, with at least 4 hours and up to 8 hours.

*3.4.5. Courses*

Courses should deepen theoretical and/or practical issues, with a minimum of 20 hours.

*3.4.6. Exchanges*

Exchanges should be rapid (within one week) and targeted (solve specific problems).

*3.4.7. Stages*

Stagesshould be longer than the exchanges (at least two weeks), giving preference to facilities outside the company.

***3.5. Forms of assessment***

All training must be evaluated by written tests with at least 5 essay questions or ten multiple choice questions. The minimum approval grade is 7. If not approved, the training will be considered in the learning process, being enrolled again in the near training.

***3.6. Record of training***

All training must be recorded. A certificate of attendance and knowledge upgrade should be delivered to participants, and a copy must be archived at the Office for Radiation Protection.

***3.7. Coaches Profile***

Coaches must have at least five years of experience in the area or the title of supervisor of radioprotection, with a Master's degree in pertinent area. The company's employees that address the above requirements are considered native coaches. Instructors outside the staff of the company should have their "curriculum vitae" approved by the Supervisor of radioprotection, before assuming the role of instructor.

The radiation protection supervisor must be trained by another Supervisor of Radiation Protection.

***3.8. Training program***

The program of basic training in radiation protection should be available for external audit at the Radiation Protection Service.

Table I. Number of students (Numb.Stud.) and average (AVG) notes per class.

|  |  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- | --- |
| *Class* |  | *URA* |  | *UTM* |  | *UMP* |
|  | *AVG* | *Numb. Stud.* |  | *AVG* | *Numb. Stud.* |  | *AVG* | *Numb. Stud.* |
| T01 |  | 9.36 | 7 |  | 8.59 | 17 |  | 9.00 | 24 |
| T02 |  | 9.20 | 12 |  | 8.22 | 11 |  | 8.61 | 45 |
| T03 |  | 8.66 | 9 |  | 8.00 | 13 |  | 8.90 | 33 |
| T04 |  | 8.92 | 7 |  | 8.58 | 14 |  | 8.62 | 23 |
| T05 |  | 9.08 | 19 |  | 8.66 | 21 |  | 8.58 | 32 |
| T06 |  | 9.46 | 25 |  | 9.07 | 35 |  | \*\*\* | \*\*\* |
| T07 |  | \*\*\* | \*\*\* |  | 9.78 | 18 |  | \*\*\* | \*\*\* |
| T08 |  | \*\*\* | \*\*\* |  | 8.50 | 10 |  | \*\*\* | \*\*\* |
| T09 |  | \*\*\* | \*\*\* |  | 9.43 | 61 |  | \*\*\* | \*\*\* |
| AVG |  | 9.18 | 13 |  | 8.98 | 22 |  | 8.71 | 31 |

\*\*\* no classes.

**4. Results and Conclusion**

Training was composed of lectures. A discursive individual proof, with consultation, was applied where trained operators developed radioprotection topics analyzed during the lecture.

The discursive proofs were corrected according to expected responses. After correction, all operators trained were allowed to have a look at their tests for considerations about the answers.

At URA 79 employees were trained. Employees were divided into six groups, with an average of 13 operators per class. Among the six groups, the average note was 9.2. The averages and the numbers of students per class are shown in Table I.

At UTM, 200 employees were trained (62 employees of INB, 134 outsourced employees, two doctoral students of the Institute of Biology of the University of São Paulo and two employees of CNEN/Poços de Caldas). Participants were organized into 9 classes with 22 students. Their average note was 8.1, see Fig 1.

At UMP, 157 employees were trained. Five classes were held, with an average of 31 students per class; their average note was 8.71.

Small changes in how to conduct the training have been proposed and are being incorporated. The assembly of groups of employees resulted in low production of the facility, caused by lack of staff in production lines. From this observation the training program was rescheduled. Now new trainings are made in individual form. Organization of classes now occurs only for initial training. This training occurs when new formations of classes are requested which only occurs when of new employees are admitted. In these cases the classes are small, no more than 5 employees.

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