2013 International Nuclear Atlantic Conference - INAC 2013
Recife, PE, Brazil, November 24-29, 2013
ASSOCIAÇÃO BRASILEIRA DE ENERGIA NUCLEAR - ABEN
ISBN: 978-85-99141-05-2

OCCUPATIONAL EXPOSURE ASSESSMENT IN A RADIOACTIVE FACILITY: A PRELIMINARY EVALUATION

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ABSTRACT

The risk that a worker has found on the job is a function of the hazards present and his exposure level to those hazards. Exposure and risk assessment is therefore the heart of all occupational health and industrial hygiene programs involving a continuous process of information gathering. The use of a systematic method to characterize workplace exposures to chemical, physical and biological risks is a fundamental part of this process. This study aims to carry out a preliminary evaluation in a radioactive facility, identifying potential exposures and consequently the existing occupational hazards (risk/ agent) in the workplace which the employee is subject. The study is based on proposal to carry out a basic characterization of the facility, which could be the first step in the investigation of occupational exposure. For this study was essential to know the workplace, potential risks and agents; workforce profile including assignment of tasks, sources of exposure processes, and control measures. The main tool used in this study was based on references, records, standards, procedures, interviews with the workers and with management. Since the basic characterization of the facility has been carried out, consequently the potential exposure to the agents of risks to workers has been identified. The study provided an overview of the perception of risk founded at facility studied. It is expected to contribute with the occupational health program resources for welfare of the worker.

Keywords: occupational exposure, agents of risk, basic characterization.

1. INTRODUCTION

Regardless of the institution, all the activities performed may involve some risks. “Risks” is the degree of probability of occurrence of a determined event, in certain period of time [1].

In general the institutions manage the risk, in some degree, identifying it, analyzing it and then, evaluating if the risk should be modified by treatment in order to attend the specific criteria [2].

The process of the risks assessment is the process global of identification, analysis and evaluation. The identification of risks is a process of search, recognition and description of them. The identification of risks involves the identification of sources of risk, events, their causes and their potential consequences [2].

According to the Brazilian literature the risks environmental are divided in five groups, the physical agent, chemical, and biological, of accident and conditions ergonomic inadequate in the workplaces that, in function of their nature, concentration or intensity and exposure time are capable of causing adverse effects to de worker´s health. [3, 4].

This study aims to carry out a preliminary evaluation in a radioactive facility, identifying the potential exposures for worker. The proposal is to perform a basic characterization of the facility relating the information available about the workplace, tasks of workers and the potential exposure agents. For this, reports, records, procedures, interviews and observations were analyzed.

2. METHODOLOGY

A descriptive and exploratory study, with qualitative approach of potential risks at a radioactive facility of the *Instituto de Pesquisas Energéticas e Nucleares*, IPEN/CNEN-SP was carried out. The data were collected between the months of April and August, 2013.

The facility population is about of the 93 employees, being that the sample studied was constituted almost in their totality corresponding 98.9% of whole of population.

The study involved two steps. The first step consisted to carry out an approach about the basic characterization of the radioactive facility, through knowledge of the workplace, organization management, the form how it is organized and the staff of occupationally exposed individuals, OEI´s. In addition, was performed a survey of sample current profile considering some of variables concerning to persons, such as gender, age and education [5].

In second step was carried out a qualitative assessment of environment/workplace including processes/materials involved, type of task performed by workers, time of work, use of equipment of protection individual and control measures. This step aims to identify the various elements of the workplace (risk agents) and its potential risk to each of OEI´s.

In this sense, a questionnaire was applied to the workforce through interviews with the managers of each task group, which some of them chose to self-complete the questionnaire. The questionnaire was structured with questions about environmental work conditions, task performed, potential risk agents and workplace and individual monitoring with the purpose of characterization of the facility.

3. RESULTS AND DISCUSSION

The sample studied was composed by 92 employees, divided in eight groups according to the task performed, they are: radioisotopes primary production, labeled compounds and lyophilized reagents, quality control, quality assurance, research and development, administrative staff and radioprotection team. In Fig. 1 is illustrated this distribution in percentages of workers of each group task.

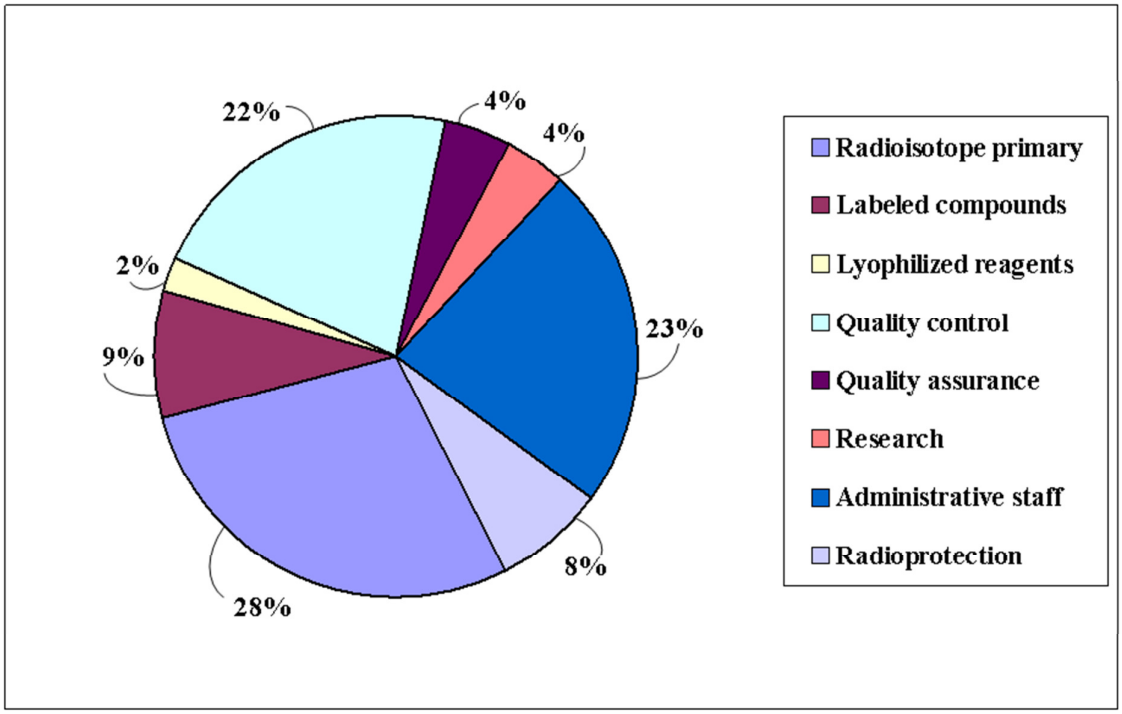

Figure 1: Workforce distribution according to the task performed.

The workforce distribution showed in Fig. 1, 26 workers belong to radioisotope primary production (28%), 8 workers in labeled compounds (9%), 2 workers in lyophilized reagents (2%), 20 workers in quality control (22%), 4 workers in quality assurance (4%), 4 workers in research (4%), 21 workers in the administrative staff (23%) and 7 workers belong to radioprotection team (8%).

To investigate the distribution of possible adverse health effects is required previously that the institution provide information concerning characteristics persons. Some variables related to persons, used in descriptive studies, were identified, such as, age gender education level. [1].

The age of employees varied from 23 to 69 years old, being that the most of the workforce is concentrated in the range of 51 and 60 years old (41.9%). The average age obtained was 50.85 years old. Regarding gender was predominated the male (73.11%) and about the educational level, 69 employees had technical level (74.19%) and 23 presented higher level (24.73%).

The basic characterization of the facility requires a good knowledge of processes and methods of work, jobs and tasks carried out by workers, environmental agents and consequently the potential risks associated.

A subjective evaluation about the workplace, workforce, environmental agents and potential risk was obtained by managers of each group and with the assistance of radioprotection

supervisor. In general, the exposure strategy of the work group was considered homogeneous, since that each specific group carries out the same task [6].

The Table 1 shows the potential occupational risks based on the task performed.

Table 1: Occupational risks identified on workplace according to task performed

Occupational Risk / Task	Physical	Chemical	Biological	Ergonomic	Accident
Production*	X			X	
Quality Control	X	X	X	X	X
Quality Assurance				X	
Research and Development	X	X	X		
Administrative staff	X			X	X
Radioprotection team	X			X	

*The production includes the groups: R**adioisotopes primary, labeled compounds and lyophilized reagents.**

An inventory of the processes involved in facility studied is described below, where was taken account that each worker have homogeneous exposure, i.e., since the group performing the same task.

3.1. Production

The production is responsible by synthesis and fractionation of radiopharmaceuticals, producing routinely radioisotopes primary, labeled compounds and lyophilized reagents. The workload of this group is about 36 hours weekly.

To concretion the task are used chambers of ionization, pipettes handlers. During the running task are generated liquid and solid wastes that are stored in tanks and rooms for decay.

3.1.1. Radioisotopes primary

The radioisotopes primary, are radiopharmaceuticals products ready to the use [7]. The radionuclides handled in this group to production of radioisotopes primary are: Gallium-67, Thallium-201, Chromium-51, Potassium-32, Iodine-123 and Iodine-131. These radionuclides are in liquid form and are emitters of beta particles and gamma radiation, as product radioactive decay.

3.1.2. Labeled compounds

The labeled compounds are non-radioactive components for labeling with a radioactive component [7]. In this group are handled radionuclides such as, Chromium-51, Lutetium-177, Samarium-153, Fluorine-18, Yttrium-90, Iodine-131 and Iodine-123. The radionuclides used to production of labeled compounds are in liquid form and emit beta particles and positron.

3.1.3. Lyophilized reagents

The lyophilized reagents are non-radioactive substrates, which are subsequently labeled with a radioactive element, Technetium-99m. There is no presence of ionizing radiation for workers this group. However, the staff may be occasionally to assist in the radiological working area.

It was considered that the workers involved in radioisotopes/radiopharmaceuticals production are exposed to physical risk, specifically the ionizing radiation, and ergonomic risks from the handling of radioisotopes cited above. Although, only the workers that produce the lyophilized reagents are exposed only ergonomic risk.

The Table 2 shows the potential risks and agents in the radioisotopes/radiopharmaceuticals production.

Table 2: Potential occupational risks and agents during the production

Production of radioisotopes/radiopharmaceuticals	
Risks	**Agents**
Physical	Ionizing radiation
Ergonomic	Weight lifting
	Repetitive movements, overload work

3.1.4. Protective/control measures

All workers this group use personal protective equipment (PPE), such as, hood, glasses, face shield, air respirators (utilized only in the production of lyophilized reagents) apron, disposable gloves, sneaker, pants, overalls. It also makes use of collective protection (CPE), for example, cells, glove-boxes (only used in the production of labeled compounds), tongs, pipettes, glass plumbiferous, lead walls, safety shower/eye wash, identification of laboratories sign and extinguishers of fire.

The occupational risk is accomplished by workplace monitoring and individual monitoring, taking in account the nature and intensity of normal and potential exposures. The OEI uses a personal thermoluminescent dosimeter (TL).

Regarding to ergonomic risk, when identified, it is made the adjustment comfortable and productive between the individual and his work station.

Due these control measures used, the exposure of worker to physical, chemical, biological risk and of accident conditions is unlikely.

3.2. Quality Control

The quality control is responsible by execution of tests in radioisotopes primary, labeled compounds and in lyophilized reagents for control of radiopharmaceuticals products to be used in patients in clinics and hospitals.

The workload of this group is specific, so shift work is very common. Most of workers operate during 36 hours and 48 hours per week.

The tests are performed in analytical laboratories (Lab) subdivided in: technetium labeled reagent Lab, labeled compounds Lab, radioisotopes primary Lab, biological, microbiological Lab, prime materials Lab, environmental Lab and viable and non-viable particles Lab.

The workers which carry out these tasks are potentially exposed to all radionuclides produced in the facility.

In addition, during the handling of the radioisotopes, there is also the handling of substances chemical, such as, methanol, sodium chloride, sodium phosphate, ammonium acetate, ammonium hydroxide, hydrochloric acid and other solvents volatile and flammable.

The handling of material biological is observed during the radiopharmaceuticals distribution tests in animals (mice) of experimentation.

Usually, while running task liquid and solid wastes are generated, which are disposed in tanks and stored in rooms for decay. After a time period, the liquid waste is released into a sewer own and the solid waste is disposed to conventional garbage collection.

The Table 3 shows the potential risks and agents to OEI´s during the quality control task.

Table 3: Potential occupational risks and agents in the quality control

Quality Control	
Risks	**Agents**
Physical	Ionizing radiation
	Noise
Chemical	Flammables substances, organic solvents
Biological	Contact with secretions
	Contaminated objects
Ergonomic	Repetitive Movements
	Situations causing psychic stress
	Weight lifting
Accident	Probability of fires and explosions

3.2.1. Protective / control measures

All workers this group uses PPE (hood, goggles, air respirators, apron, overalls, sneaker and disposable and sterile glove) as CPE (fume hood, pipettes, signaling for laboratory and for fire extinguishers) and also use of shielding (plumbiferous glass, and lead wall). The workforce is constantly monitored by hands and feet detectors make use of personal dosimeter (TLD) and body whole counting.

3.3. Quality Assurance

The quality assurance is a broad concept that involves all the aspects individually or collectively, which may influence the quality product. Represents the sum of all the actions performed in order to ensure that medical products present the quality required for its intended use. The quality assurance incorporates the Good Manufacture Practices and the quality control [8].

The workload of this group is assumed during 40 hours weekly and carry out your asks inside rooms within the facility. There is no manipulation of radioisotope/radiopharmaceutical, chemical materials or contaminated objects involving this group. The potential risk exposure is pointed to agents ergonomic. The Table 4 presents the risk and agents found in this laboratory.

Table 4: Potential occupational risk and agents in the quality assurance

Quality Assurance	
Risk	**Agents**
Ergonomic	Inadequate postures
	Ineffective training
	Overload work
	Responsibility and emotional conflicts
	Situations causing physical or psychic stress

3.3.1. Protective / control measures

To control of the problem is to adapt working conditions to the characteristics of the human, and to find productive and comfortable fit between the individual and workplace/work station.

3.4. Research and Development

This group can be divided in three subgroups. The first one is responsible for production of radioisotope primary, as the Copper-64, used in positron emission tomography (PET).

The second subgroup is involved in development of new generator, as example Gallium-68 generator from Germanium-68 [9].

The third subgroup is responsible for labeled compounds with positron emitter. An important line of research is the development of new molecules to be labeled with Technetium-99m for use in diagnostics. There is also labeling compound for therapy in the treatment of tumors. In addition, there is the development of micro-spheres of Holmium-166 or Yttrium-99, as therapy, in case of liver cancer treatment [9].

The workload this group is about 40 hours weekly, but there are some exceptions, due the work related with the half-lives of radioisotopes. The journey can be extended on weekends.

The workforce handling several radioisotopes, such as, Technetium-99m, Thallium-201, Samarium-153, Indium-111, Iodine-123, Iodine-131, Lutetium-177, Yttrium-90, Gallium-67, Gallium -68, Fluorine-18, Potassium-32, Holmium-166, Rhenium-188 and Copper-64. These radioactive materials are available in liquid, gaseous and solid forms and emit beta particles, positrons and gamma rays.

There are radioactive waste productions that are segregated; the solid waste is collected and disposed by radioprotection team and the liquid waste disposed in specific sinks.

The workforce also handling some chemical substances as, methanol, carbon monoxide, methyl ethyl ketone, n-hexane, xylene, chloroform and lead for manufacturing of shielding.

The research and development of new radiopharmaceuticals, requires bio distribution studies in animals (mice), so, there is possibility of contact with contaminated objects.

Among the risks existing for workers this group was concluded the potential exposure to physical, chemical and biological risks. The Table 5 presents the potential risks and agents.

Table 5: Potential risk and occupational agent in research and development

Research and Development	
Risks	**Agents**
Physical	Ionizing radiation
Chemical	Organic solvents
	Chemical products
Biological	Contaminated objects

3.4.1. Protective / control measures

Analytical equipment is used at research and development activities. The handling of radioactive material is constant, being necessary to carry out radiological monitoring. To reduce exposure the radiation is used lead shield, both PPE (dosimeter, goggles, aprons, disposable/sterile glove and sneaker) and CPE (fume hood, glove-boxes, cells, tweezers, pipettes, plumbiferous glass, lead wall, signaling for PPE, laboratory and fire extinguishers).

In addition to the risks cited in the questionnaire, the comments made by the manager respondent about the fume hood efficiency to avoid the chemical contaminants dispersion in the air, and also the absence of shower/eye wash in the research laboratory were considered.

3.5. Administrative/infrastructure staff

This work group carries out tasks in support to research radioisotopes/radiopharmaceuticals, production providing basic infrastructure to facility operations. The workload is 30 hours per week. It was mentioned that there is no handling of radioisotopes/radiopharmaceuticals or chemical substances, however all workers remain within radioactive facility and can access both the laboratories of operation and hot cells processing as the sector of packaging [10]. For this reason, the staff occasionally may be exposed to physical, accident conditions and mainly ergonomic risks.

The Table 6 presents the potential risks and agents.

Table 6: Potential occupational risks and agents for administrative staff

Administrative Area	
Risks	**Agents**
Physical	Ionizing radiation
Ergonomic	Inadequate postures
	Ineffective training
	Situations causing physical or psychic stress
Accident	Probability of fires or explosions

3.5.1. Protective / control measures /

Although there is no handling of radioactive material, the staff may occasionally to access the radiological work area. Routinely, to evaluate the radiation levels received by worker, measures, using body whole counter, are performed in accordance with the Radioprotection Plan. When appropriate, the work conditions are adapted to provide the adjustment comfortable and productive between the individual and his workplace.

3.6. Radiological Protection Team

The radiological protection team is responsible to keep under control the sources of radiation, the radioactive wastes and effluents, the control doses received by occupationally exposed individuals, by public general and environmental, the control of workplace and of the equipment for radiation monitoring. [10, 11].

The workload of this group is 36 hours per week, being carried out in shift work. The radioprotection team gives support to workforce involved in research and radioisotope production therefore, may be exposed in potential, to risks cited in Table 7.

Table 7: Potential risks and occupational agents to radiological protection team

Radiological Protection Team	
Risks	**Agents**
Physical	Ionizing radiation
	Aerosols in environment (particles generated by work related)
Ergonomic	Shift work
	Weight lifting
	Situations causing physical or psychic stress

3.6.1. Protective / control measures

To evaluate the radiation levels the radioprotection team uses specific detectors of radiation. During radiation monitoring to control of exposure in the workplace, there is the probability to detect radionuclide dispersed in the air, for example: iodine, technetium and gallium. Often are used the PPE (cap, air respirators, apron, glove disposable, sneaker, boot, pants, overalls, and thermoluminescent dosimeter).

4. CONCLUSION

Exposure to intense environmental agents can produces adverse health effects. For example, some agents may have reversible systemic effects, or be irritants and other can be carcinogenic. In others cases, cannot present any adverse health effect. However, where a mixture of different agents is assessed, the overall risk category should normally be that of the most hazardous component.

The object this study was the identification of environmental agents found in a radioactive facility in function of tasks or jobs exercised by workers. Therefore not was object of study to evaluate the effects on worker´s health arising of potential exposures.

Since it is a radioactive facility the agent "ionizing radiation" was priority, but according to the radioprotection protection team, in general, the workers of this facility show potential exposure to physical, chemical, biological, ergonomic and accident risks, based on jobs held by workers over time.

Routinely, the radioprotection team performs an effective control, applying the techniques of individual and workplace monitoring, as well as the data assessment exposure in accordance with national and international standards.

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