Basic Characterization of a Radioactive Facility and Evaluation of Risk Agents

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Abstract. This is an exploratory and descriptive study with qualitative and quantitative approaches to investigate the basic characterization of a Brazilian radioisotope production facility through ample knowledge of the workplace, workforce, task performed and identification of present risk agents in labor environment. The studied sample was composed by 102 workers distributed in eight work processes. Data were collected from April 2013 to July 2014 by applying questionnaire forms and complemented by interviews and observations. The descriptive statistical analysis included ANOVA test and non-parametric tests, among others. For the purpose of this study, there was adopted a significance level of 5% ($p<0.05$). The analysis of socio-demographic variables demonstrated that male gender predominated in total sample (74.5%) and the mean age of the workers was (51.8 ± 1.7) years. The largest percentage of the responders (70.6%) was technician-level workers. Regarding task-related exposure, there was considered that all groups presented the same exposure profile. At the workplace, there were identified 17 risk agents, including physical, chemical, biological, ergonomic and accident risks. The workforce was categorized into 3 risk groups according to relative frequency distribution of the occupational risks. Among the sixteen qualitative variables studied at the workplace, only three of them did not demonstrate relative frequency. The only variable that showed association with the three risk groups was the possibility of the contact with ionizing radiation. The study provided an overview of the perception of occupational risk at the facility. According to the results obtained by statistical analysis, most of the qualitative variables presented statistically significant association ($p<0.001$) related to the occurrence of occupational risks. Even though the workers may be potentially exposed to different risk agents, the ionizing radiation was the main physical risk factor observed in this facility.

KEYWORDS: occupational risk; basic characterization; workers profile; qualitative assessment.

1 INTRODUCTION

The occupational risk assessment is a structured and systematic process, which depends on the correct identification of probable risk factors and agents, through qualitative and/or quantitative evaluation of worker exposure [1].

The first step in workplace exposure risks assessment requires the execution of a basic characterization that enable the qualitative analysis, which comprises the collection and appropriate structure of subjective information about the workers and their work environment. Moreover, an analysis of the socio-demographic variables was carried out for the purpose of a better understanding of the sampling distribution [2-4].

There is a significant difference between processes involving workers of a Brazilian radioisotopes production facility and processes involving workers of other professional categories. Relevant particularities considered to this study comprise the exposure to different risk agents according to their nature: physical (ionizing radiation), chemical (chemical substances involved in the processes), biological (contaminated objects), ergonomic (stress-causing situations) and accidents (fires and explosions) [5-7].

The main purpose this study was to carry out the basic characterization of a Brazilian radioisotope production facility through ample knowledge of the workplace, workforce, task performed and identification and evaluation of occupational risk agents in the workplace.

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2 METHOD AND MATERIALS

The population of the studied Brazilian radiopharmacy facility is composed of 204 workers: 102 federal public employees (50%), 57 contractors (27.94%) and 45 students / trainees (22.06%). Nevertheless, the studied sample was limited to public employees, which represented 50% of total facility population.

The development of this study comprised a detailed evaluation process, covering the basic characterization of the workplace, workgroups and the identification of the probable occupational risks related to execution of workers´ tasks [6]. The exploratory analysis involved descriptive statistical analysis of qualitative variables related to the workplace.

From April 2013 to July 2014 a variety of methods were used to gather both quantitative and qualitative data through a self-completed questionnaire, interviews and direct observations. The respondents of the questionnaire were the managers of each workgroup at the facility. The structured questionnaire was based on work processes involving materials used to new radiopharmaceuticals research and production, workplace conditions, personal and collective protection equipment and identification of provable risk agents related to the workers´ tasks.

The software's Statistical Package for Social Science (SPSS) version 17, Minitab 16 and Microsoft Excel 2010 were used for statistical analysis [8, 9]. Initially, qualitative and quantitative variables were studied through descriptive statistics, considering frequency and distribution of a particular event.

The statistical methods comprised nonparametric tests (Equality of two proportions, Chi-square and Yates correction), ANOVA test, descriptive measures of location (mean, median and quartiles) and dispersion (standard deviation and coefficient of variation). Moreover, it was used a P value of 5% to determine statistical significance. Therefore, all confidence intervals were constructed at a 95% statistical confidence level [10-12].

3 RESULTS

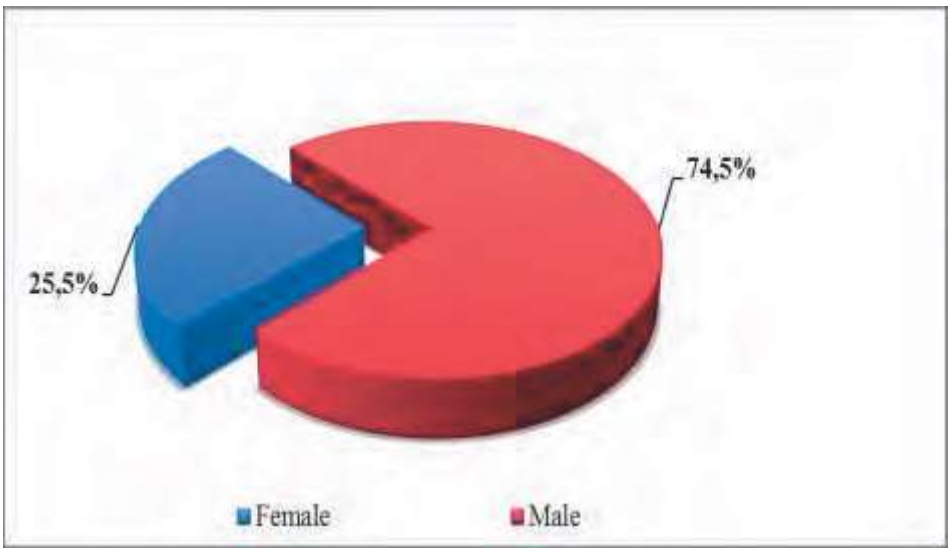
3.1 Basic characterization – Evaluation of occupational exposure

Based on subjective information obtained by questionnaire about workplace, workforce and risk agents, the 102 responders were distributed into eight work processes: 27 workers in production of primary radioisotopes (representing 26% of the total sample), 8 workers in production of labeled compounds (8%), 2 workers in production of lyophilized kits (2%), 24 in Quality Control (23%), 4 in Quality Assurance (4%), 5 workers in Research & Development of methods and Innovation (5%), 25 in infrastructure team (24%) and 8 in Radioprotection team (8%).

3.1.1 Workers profile – analysis of sociodemographic variables

The equality of two proportions test was used to determine the distribution of the relative frequency (percentage) of socio-demographic variables, such as gender, educational level and age. Figs. 1 and 2 illustrate the distribution of workers according to gender and educational level respectively.

Figure 1: Distribution of workers according to the gender



The analysis of sociodemographic variables showed a predominantly male-gender population in the sample (74.5%).

The results of distribution related to the educational level variable (Fig.2) show that 72 workers have technical level, representing the majority of the sample, about (70.6%) of total respondents.

Figure 2: Distribution of sample according to the educational level

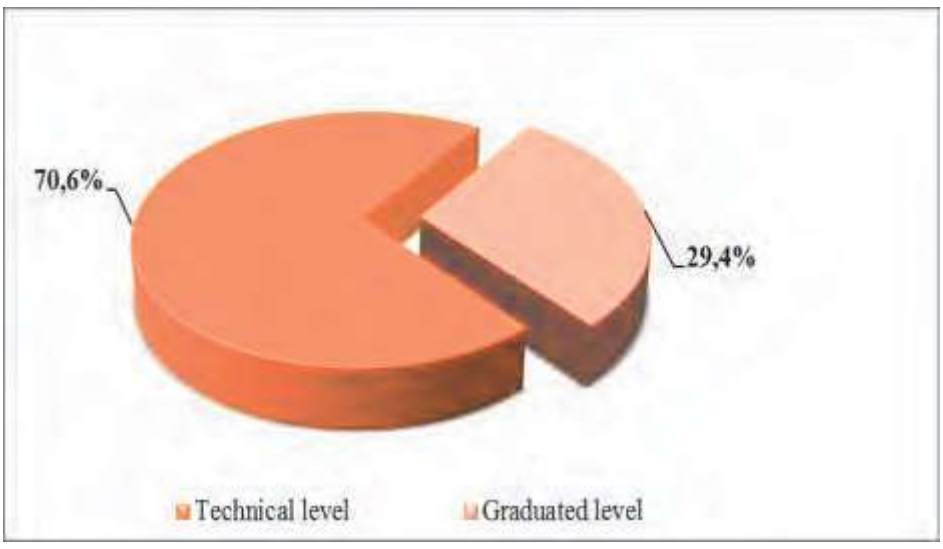


Table 1 shows the complete descriptive analysis for the age variable.

The average age of workers was about (51.8 ± 1.7) years. Table 1 demonstrates that the standard deviation (8.6) and the CV of 17% can be considered low (<50%) when compared to the average. These indicators demonstrate low variability and consequently indicate the homogeneity of data.

Table 1: Complete descriptive analysis for the age variable.

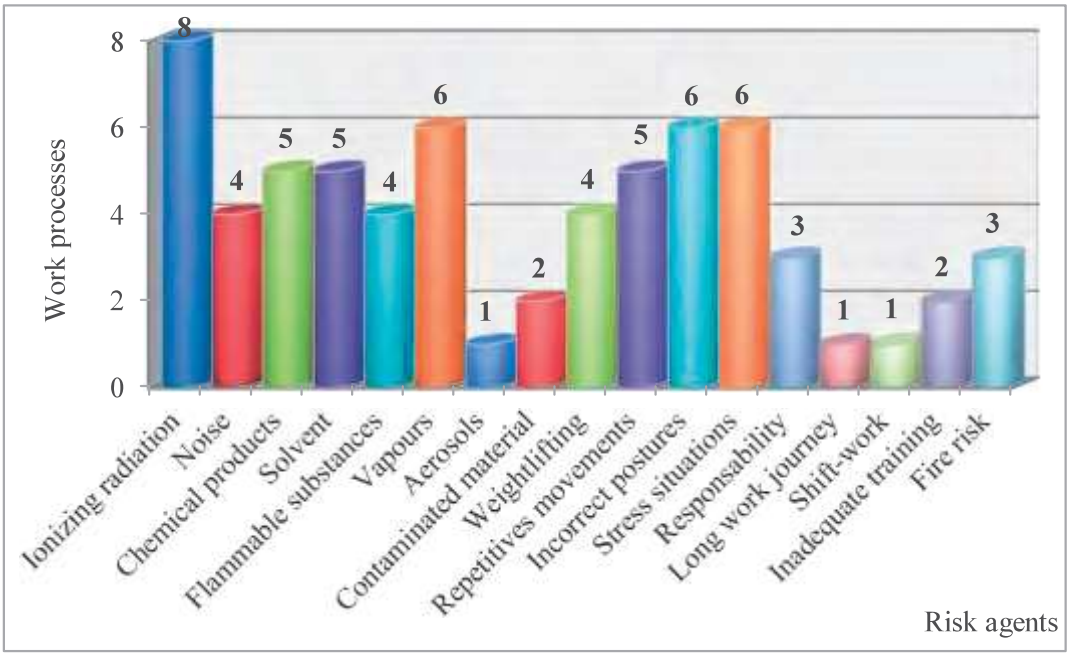
Descriptive analysis	Age
Mean	51.8
Median	52
Standard deviation	8.6
Coefficient of variation (CV)	17%
1º Quartiles (Q1)	49
3º Quartiles (Q3)	57
Minimum	24
Maximum	69
Number of workers (sample)	102
Confidence interval (CI)	1.7

3.1.2 Qualitative assessment of occupational risk agents

The questionnaire used in this research enabled to identify seventeen occupational risk agents at the facility, considering the workplace, work processes and manipulations of materials.

Fig. 3 shows the seventeen risk agents identified at workplace, as well as their frequencies in the eight work processes.

Figure 3: Identification of risk agents related to work processes



As observed among the work processes, ionizing radiation is the most common risk agent, followed by vapors agents, incorrect ergonomic postures in workplace and stress work-related situations. Whereas workplace is a radioactive facility, the possibility of exposures to ionizing radiation is inevitable, due to the influence of the radiation fields from the production of radioisotopes and radiopharmaceuticals products.

3.1.3 Homogeneous exposure groups (HEGs)

Workgroups presenting the same profile of exposure to a specific range of occupational risk agents are called homogeneous exposure groups (HEGs). Based on a systematic assessment of the subjective information collected during the basic characterization of the facility, it was carried out a survey that enabled the determination of HEGs.

Even though the facility counts on eight different work processes, it was observed that two different profile groups are exposed to the same agent risks. As a matter of fact, due to similar characteristics of performance tasks, the production of the primary radioisotopes group and labeled compounds group are occupationally exposed to the same agent risks with similar frequency.

Therefore, there were considered for this study seven HEG s: **production** (primary radioisotopes and labeled compounds), **lyophilized reagents** (kits), **quality control**, **quality assurance**, **research**, **infrastructure** and **radioprotection**.

3.2 Quantitative-qualitative assessment of occupational risks

The only risk agent able of quantification in this study was the ionizing radiation. Therefore, a statistical analysis was performed in order to estimate which of the identified risks agents (qualitative variables) could be associated with the occurrence of the occupational risks in established HEGs.

Initially, nonparametric statistical test as “equality of two proportions” was applied to the analysis and characterization of the relative frequencies distribution.

The qualitative dependent variable occupational risk has been characterized according to its relative frequency in each HEG.

Frequency analyses were performed for the occupational risks identified according to their type (physical risk, chemical, biological, ergonomic and accident), making possible to classify them into three main categories of risk (risk groups 1, 2 and 3). These three groups are exposed to similar work-related risk types. Table 2 presents the analysis of frequencies performed by the equality of two proportions test among the three risk groups.

Table 2: Relative frequency distribution of the variable occupational risk among the risk groups.

Group	Occupational risk	Number of workers (N)	Frequency (%)	p-value
Risk 1	Physical, ergonomic and accident	29	28.4	0.020
Risk 2	Physical, chemical and ergonomic	45	44.1	Ref.
Risk 3	Physical, chemical, biological, ergonomic and accident	28	27.5	0.013

Note: p-value considered statistically significant was $p < 0.05$.
P value Ref. (reference): the response prevalent level or the one that shows the highest frequency. This was used only when the variable presented three or more response levels.

According to Table 2, risk group 2 is composed by HEGs, production, reagents and radioprotection, and showed the highest percentage (44.1%). Risk group 1 is composed by HEGs, quality assurance and infrastructure and showed a percentage similar to risk group 3, consisting by HEGs of the quality control and research. This group is exposed to five types of risk (physical, chemical, biological, ergonomic and accident).

3.2.1 Relative frequency distribution of the qualitative variables

The relative frequencies of the qualitative variables could be analyzed based on questionnaire results obtained by equality of two proportions test. The data analyze showed that the sixteen qualitative variables were related to the workers´ tasks: radionuclides used in the radiopharmaceuticals production, mode of decay, physical aspects, chemicals products handling, temperature, presence of noise, presence and possibility of contact with ionizing radiation, handling and storage of dangerous chemical products, chemical contaminants dispersed in the air (vapor), biological material handling, biological contaminants dispersed in the air (aerosols), probability of fires or explosions, inadequate lighting, physical workload (manual weightlifting and long work journey), mental workload (responsibility) and stressful situations.

According to variables data analysis, only three of them - extremes temperature, biological contaminants dispersed in the air (aerosols) and inadequate lighting – did not present relative's frequencies. These variables were not selected by the respondents.

The results of the relative frequencies analysis (13 variables) were used to measure the statistical association between occupational risk (dependent variable) and its possible agents and factors (other qualitative variables). In this analysis, there were used the chi-square test and Yates correction test. Even so, the Yates correction test was only applied in the case results were smaller than 5 responses.

Based on the results of the thirteen analyzed variables, it was observed that only two of them (physical form of the radionuclides and stressful situations) did not present a statistically significant association degree. The remaining eleven variables did present a significant statistical association degree with the risk groups, presenting percentage values over 60%.

Regarding the results, risk group 1 showed statistically significant degree of association ($p<0.001$) only with two variables: presence and possibility of contact with ionizing radiation (100%) and probability of fire or explosion (86%).

Risk group 2 demonstrated a significant association with eight variables: radionuclide, type of emission, chemical products, presence and possibility of contact with ionizing radiation, noise, chemical products handling, physical and mental workload. Results showed association of 100% with the physical workload.

Risk group 3 presented a significant degree of association with all variables, with percentage over 80% in all cases except for mental workload variable.

The only variable that showed significant association with all three groups was the presence and possibility of contact with ionizing radiation.

The statistical analysis of p-values indicates that only two variables showed a significance level of p-value <0.05. These variables are: physical form ($p = 0.937$) and stress situation ($p = 0.275$). Thus, these two variables are not statistically associated with the identified occurrences of occupational risk in the workplace. Therefore, the statistical analysis provided eleven risk agents associated with the occurrences of occupational risk among the HEGs.

3.3 Descriptive statistical analysis of the sociodemographic variables related to occupational risk

The ANOVA test was applied to compare the mean age among the three risk groups (Risk 1, 2, 3). Table 3 shows the descriptive analysis between the age variable and risk groups.

Table 3: Comparison of age and risk groups

Descriptive analysis	Risk groups		
	Risk 1	Risk 2	Risk 3
Mean	53.8	51.9	49.4
Median	56	52	49
Standard deviation	9.3	6.9	10.0
Coefficient of variation	17%	13%	20%
Minimum	24	30	27
Maximum	69	67	65
Number of workers	29	45	28
Confidence interval	3.4	2.0	3.7

According to the results from Table 3, there is no difference between the mean age among the three risk groups, even in the case of risk group 1 (workers exposed to physical risk. chemical and ergonomic) which presents the highest average of 53.8 years. Then, workers´age is not the factor that influences the occurrence of the risk.

Yates correction test was applied to analyze the variables "gender" and "educational level". Table 4 shows the statistical association degree between the occurrence of occupational risk in the workplace and gender (female and male), as well as the association degree between the occurrence of occupational risk in the workplace and educational level (technicians or graduate).

Table 4: Association degree of the risk groups with the variables: gender and educational level;

Variables		Risk 1		Risk 2		Risk 3		Total		p-value
		N	%	N	%	N	%	N	%	
Gender	Female	6	21	9	20	11	39	26	25	**0.144**
	Male	23	79	36	80	17	61	76	75	
Eduactional level	Technical	21	72	34	76	17	61	72	71	**0.387**
	Graduated	8	28	11	24	11	39	30	29	

Note: p-value significance level adopted ($p < 0.05$)
N: number of workers.

As shown in Table 4, neither the gender nor the educational level of workers present statistically significant association with the risk (p-values > 0.05) and both variables bring similar percentages.

4 CONCLUSIONS

This study allowed to carry out the basic characterization of a Brazilian radioactive facility and enabled to identify seventeen occupational risk agents present at workplace. The main physical risk agent observed among them was the ionizing radiation, probably due to the daily handling of radioactive materials.

The quantitative and qualitative approach carried out through the use of statistical methodology and subjective information allowed to find out the real conditions of workplace, work processes and exposure of workers.

The strategy for decision-making for workers´ monitoring was founded on HEGs workgroups, which presented similar exposures to risk agents.

Based on this study, our recommendation for future actions is that the homogeneous exposure groups and risk agents must be periodically analyzed and modified whenever necessary, taking into account

that each new evaluation of the risk agents in the workplace should be carried out from the basic characterization phase.

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