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RADON EXPOURE AT IPEN NUCLEAR MATERIALS STORAGE SITE

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ABSTRACT

It is well known that NORM (Naturally Occurring Radioactive Materials) is hazardous to health and it has long been recognized that work with NORM can rise significantly the exposure in the workforce. By far, inhalation of ^{222}Rn represents the main contribution to the effective dose received by the workers. At the Instituto de Pesquisas Energéticas e Nucleares (IPEN), São Paulo, Brazil, there is a facility dealing with great uranium and thorium concentrations, the nuclear materials storage site. In this study it was assessed the occupational exposure to ^{222}Rn at IPEN nuclear materials storage site through the committed effective dose received by workers exposed. The radiation dose due to radon inhalation was calculated considering International Commission on Radiological Protection procedures through the radon intake at nuclear materials storage site and the dose conversion factor. Radon measurements were carried out through the passive method with solid state nuclear track detectors (Makrofol E), over a period of 21 months, changing the detectors every three months, from December 2004 to September 2006. It were monitored 13 points at nuclear materials storage site and one at the ante-room for transfer materials. The ^{222}Rn concentrations in the air varied from 196 to 2048 Bq m^{-3}. The committed effective dose results varied from 4.1 to 5.4 mSv y^{-1} at the nuclear materials storage site, according to the working time. The effective committed doses received by workers are below 20 mSv·y^{-1}. This value is suggested as an annual effective dose limit for occupational exposure by ICRP 60.

1. INTRODUCTION

Over the last years, exposures to enhanced levels of natural radiation came into focus of radiation protection. Among the exposure sources taken into consideration it can be mentioned occupational activities in which materials containing enhanced levels of naturally occurring radioactive materials are handled, which may lead to occupational significant exposures and to exposures of the public [1, 2, 3].

The exposure situations can be classified as practice or intervention. Practices are situations in which human activities can increase the overall exposure natural radiation and where operational or regulatory controls could optimize and limit the future exposure. At the interventions, the sources of exposure and the exposure pathways are already present and the only type of possible action is intervention to reduce the exposure [4].

It is well known that NORM (naturally occurring radioactive materials) and TENORM (technically enhanced naturally occurring radioactive materials) are hazardous to health and it has long been recognized that work with NORM and TENORM can rise significantly the exposure to the workforce [1, 2].

The sources of most of the radioactivity in NORM and TENORM are isotopes of uranium (^{238}U), thorium (^{232}Th) and their decay progeny, mainly radon (^{222}Rn). Because radon is so short-lived, and alpha decays to a number of daughter products which are solid and very short-lived, there is a high probability of its decay when breathed in, or when radon daughter products in dust are breathed in. Alpha particles in the lung are hazardous. Inhalation of radon (^{222}Rn) represents the main contribution to the effective dose received by the workers. Epidemiological studies have demonstrated that exposure to alpha-particle emitters, mainly ^{222}Rn and its daughters increase the risk of cancer [5].

According to International Commission on Radiological Protection the recommended action level for radon in aboveground workplaces is 400 Bq m^{-3} and remedial measures should be considered. If it is not possible to reduce the radon levels below the action level, it is necessary the application of dose limits.

At the Instituto de Pesquisas Energéticas e Nucleares (IPEN), São Paulo, Brazil, there is a facility dealing with great uranium and thorium concentrations, the nuclear materials storage site where safeguarded materials are stored. In order to estimates the occupational exposure due to radon inhalation, it was determined the radon concentrations at the place and it was assessed the effective committed dose for workers.

Radon measurements have been carried out through the passive method with SSNTD (Makrofol E), due to their simplicity and long-term integrated read-out. The detectors exposure period is three months, covering December/2004 to September/2006. The committed effective dose due to radon inhalation was obtained from radon intake and conversion factor, according to International Commission on Radiological Protection procedures.

2. MATERIALS AND METHODS

The ^{222}Rn concentration was obtained by the passive detection method with solid state track detectors into diffusion chambers. Circular pieces (2 cm of diameter) of Makrofol-E were used as detector. As a diffusion chamber, a hemispherical housing of 1.5 cm radius with a filter membrane was selected. This glass filter membrane allowed approximately 98% of the radon to diffuse and suppressed thoron gas to 0.5%.

It were monitored 13 points at nuclear materials storage site, during 21 months. After exposure for approximately 3 months, the detectors were collected and replaced by fresh ones. The detectors were etched in PEW40 solution at 70ºC for 2 hours in a constant temperature bath. After etching, the detectors were washed, dried and scanned under a Carl Zeiss microscope for track density measurements. The background is 1500 tracks per cm^2. Using a calibration factor of 0.0234 ± 0.0045 tr cm^{-2} per Bq $m^{-3}\cdot d$, obtained with Pylon model RN-150 calibrated radon gas source, the track density is converted to radon concentration in the environment.

The radon concentration was calculated through the following equation [6]:

$$C = \frac{D}{k \cdot t} \tag{1}$$

where:

C is the radon concentration (Bq m^{-3})
D is the track density (tr cm^{-2})
k is the calibration factor (tr cm^{-2} per Bq $m^{-3}\cdot$d)
t is the exposure time (d)

3. RESULTS AND DISCUSSION

3.1 Radon Concentrations

The contribution from ^{222}Rn inside the nuclear materials storage site was determined through the passive method with solid state nuclear track detectors (Makrofol E) using equation (1). Twenty one points were monitored at place with two detectors in each point. Table 1 shows the results of average radon concentration and standard deviation at the IPEN nuclear materials storage site obtained from December/2004 to September/2006.

According to table 1, elevated levels of radon at the IPEN nuclear materials storage site were observed, especially at the first monitored period (December/2004 to March/2005), due to poor ventilation, because the place stayed closed at the major of time. At the period between March/2005 to June/2005 it was obtained the lower value of average radon concentration due to high ventilation rates.

Table 1. Average ^{222}Rn concentration at nuclear materials storage site

Period	^{222}Rn concentration (Bq m^{-3})
Dec/2004 to Mar/2005	$(12\pm5)\cdot10^2$
Mar/2005 to Jun/2005	$(65\pm4)\cdot10$
Jun/2005 to Sep/2005	$(10\pm3)\cdot10^2$
Sep/2005 to Dec/2005	$(95\pm8)\cdot10$
Dec/2005 to Mar/2006	$(10\pm4)\cdot10^2$
Mar/2006 to Jun/2006	$(10\pm4)\cdot10^2$
Jun/2006 to Sep/2006	$(10\pm3)\cdot10^2$

3.2 Committed effective dose

The inhalation is the main pathway of radon intake. The effective committed dose due ^{222}Rn inhalation was calculated considering the International Commission on Radiological Protection procedures, the annual radon intake and the ICRP 65 [7] committed effective dose conversion coefficients.

The committed effective dose is directly dependent on the exposure period. In this study it were considered two exposure times, 2000 hours per year and 1500 hours per year, according to the work routine at nuclear materials storage site. The annual radon intake was obtained through the radon concentration, the breathing rate of 1.2 m^3 h^{-1} [8] and the exposure period assumed for each workers group considered. Table 2 presents the committed effective dose due to the radon inhalation for the workers for two working times.

Table 2. Committed effective dose (E) for workers

E(mS y^{-1}) 2000 h	E(mS y^{-1}) 1500 h
5.4	4.1

3. CONCLUSIONS

In this study radon concentration at the nuclear materials storage site were monitored through the passive method with solid state nuclear track detectors during 21 months. It were observed elevated levels of radon at the nuclear materials storage site, upper action level. Results show that the radon concentration at place should be continuously monitored and remedial measures, like improve ventilation, also should be considered.

The committed effective dose due to radon inhalation was estimated for two exposure period, in both cases, the values are lower 20 mSv y^{-1}, the annual dose limit for workers.
It should be mentioned that workers are also exposed to gamma radiation from nuclear materials at the nuclear materials storage site. So, it is very important to monitor internal and external exposure for workers.

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