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Radiological protection of Young Scientist and Scientific Researcher trainees in controlled areas of the Argonaut reactor installation: analytical approach

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Abstract: Since the increasing use of ionizing radiations in medical and industrial proceedings, recommendations and actions have been necessaries to reduce the individual radiological risks. In the Nuclear Engineering Institute (IEN), there is the Argonauta research nuclear reactor (RARG) used for producing radionuclides, neutrongraphy studies and training young scientists (YST) and scientific researchers (SRT). During their trainings, these trainees are exposed to ionizing radiations meanly during the neutrongraphyc experiments when they need to adjust neutrongraphy plates in front the J9 channel with the RARG in critical condition. At this moment, they are exposed to neutron and gamma radiations in the RARG hall. This paper evaluated the gamma and neutron expositions that YST and SRT are submitted during the neutrongraphy experiments, by using area monitors to measure the ambient dose equivalent rates in two points near to J9 channel. Considering only this experiment, there was found that the annual individual effective dose could reach up to 2.5 mSv, which is more than 150% of the annual dose to member of the public (MP), but below the annual effective dose to occupationally exposed individual (OEI) as a worker. The question is if YST and SRT should be considered an OEI or a MP. This question is answered through an analytical approach of the regulations and recommendations. The conclusion is that YST and SRT shall be controlled as OEI, but must be submitted to MP' restriction doses.

Keywords: Radioprotection, occupacionally exposed individual, worker, public monitoring control, facility safety.

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Proteção radiológica de jovem cientista estagiário e pesquisadores bolsistas em áreas controladas da instalação do reator Argonauta: abordagem analítica

Resumo: Desde o crescimento do uso das radiações ionizantes em procedimentos médicos e industriais, recomendações e ações têm sido necessárias para minimizar os riscos radiológicos pessoais. No Instituto de Engenharia Nuclear (IEN), está instalado o reator de pesquisa nuclear Argonauta (RARG), usado para produção de radionuclídeos, estudos de neutrongrafias e treinamento de jovens cientistas (JCT) e pesquisadores bolsistas (PBT). Durante o treinamento, esses treinandos são expostos a radiações ionizantes, principalmente nos experimentos de neutrongrafia, quando é necessário ajustar as placas de filmes neutrongráficos no canal da janela J9 do RARG, que está operando em condição de criticalidade. Nesses momentos, os JCT e PBT são expostos a radiação gama e neutrons durante a permanência no salão do RARG. Mediante medições das taxas de equivalente de dose ambiente para gama e neutrons nos pontos próximos do canal J9, verificou-se que as doses efetivas individuais anuais poderiam atingir 2,5 mSv, superior em mais de 150 % ao limite anual para indivíduo de público (IP), mas inferior ao limite para indivíduo ocupacionalmente exposto (IOE). Nesse ponto, a questão é definir se JCT e PBT devem ser controlados como IOE ou como IP. Mediante uma abordagem analítica dos regulamentos legais, concluiu-se que, embora os JCT e PBT sejam controlados como IOE, seus limites de dose devem ser os estabelecidos para indivíduos de público.

Palavras-chave: Radioproteção, indivíduo ocupacionalmente exposto, trabalhador, indivíduo de público, segurança da instalação.

1. INTRODUCTION

Since the increasing use of radiation in medical and industrial proceedings, there has been necessary to implementing actions to reduce personnel radiological risks.

Now a days, nuclear scientific institutions are implementing programs for training young scientists (young scientist trainees – YST) and scientific researcher trainees (SRT), both YST and SRT whithout a formal employment relationship. YST and SRT frequently access nuclear facilities where they do their searches. The question is if YST and SRT are occupationally exposed individual (OEI) or member of public (MP). So, it is necessary to understand the radiological risks in which YST and SRT can be involved, in order to ensure that their annual effective doses are not higher than that proposed by the standards.

In this scenario, in the Nuclear Engineering Institute (IEN), there is the Argonaut research nuclear reactor (RARG) where periodically YST and SRT developing nuclear searches to producing radionuclides for activation reaction studies and material neutrography analyses.

There is low radiation exposition during radionuclide production process; however, neutrongraphy experiments require the person's presence in the hall to put the plate chassis in front of opened J9-channel when RARG is critical. (**Figure 1**).

Figure 1: The position place of the J-9 channel and chassis in the Argonaut reactor.

During the criticality condition, OEI are exposed to neutron and gamma radiations in the reactor hall. Because of this, it is important to evaluate the exposition time and the frequency that this operation occurs to efficiently and correctly minimize doses.

This work evaluated the gamma and neutron expositions that YST and SRT were submitted during the neutrongraphy plate adjustment operations.

2. MATERIALS AND METHODS

Periodically international organizations [1,2] and national regulatory authorities publish recommendations and regulations to guarantee the security and the safety uses of nuclear applications. Optimization recommendations and actions for expositions of OEI or worker, and MP are the most important. ICPR [3] defines:

> "Worker is any person who is employed, whether full time, part of the time or temporarily, by an employer, and who has recognized rights and duties in relation to occupational radiological protection".

In this way, Radiological Protection Section must keep a regular control of effective dose of OEI and MP, in order to attend principles of radioprotection and legal rules.

In Brazil, National Nuclear Energy Commission (CNEN) in their standard CNEN NN 3.01: 2014 [4] guides holders to ensure that employers are aware of their responsibility for the radiation-exposed workers and public individuals, as well about dose limits.

In Table 1 are summarised the effective dose limits established by CNEN for OEI and MP.

Table 1: Brazilian Authority' dose limits in planned exposure situations.

Type of limit	Occupational(1)	Public(2)
Effective dose (mSv per year)	20	1

(1) Averaged dose over last 5 years, but in a single year, it can not exceed 50 mSv in any year.
(2) Under special circumstances, in a single year, a higher value of effective dose could be allowed, since that the average over last 5 years does not exceed 1 mSv per year.

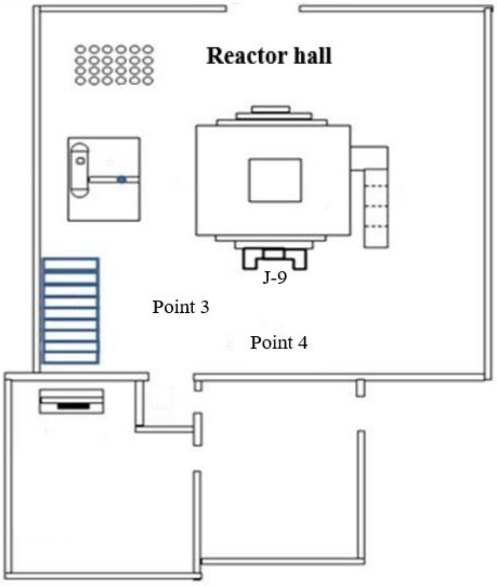
Holders and employers are responsible for evaluating the individual occupational exposition, as well as to submit to radiological monitoring individual program adequate to any nuclear worker subjected nuclear exposition. In this way, the operational quantities were measured in points that probably there are higher expositions. [5,6].

The Radiological Protection Section should remember that a trainee is a public person and must be considered a public reference level to exposition radiation.

In interview, the YST and SRT explain how will be occurred the practice, possibility to provision the protection action will be necessary in addition the routine procedures like the monitoring radiological with direct dosimetry reading to gamma exposition. During the interview also is possible to find out how frequently this operation occurred. For the neutrongraphy experiment, one plate is previously prepared to be exposited to the neutron beam for 60 minutes. The plate is positioned in front of the output J9 channel when the reactor is critical. The YST, SRT and workers get in the RARG hall to adjust the plate chassis for 3 minutes, then, go out.

In figure 2, we show the measurement points near the output J-9 channel, where the presence of a individual would be necessary to realize the practice. The ambient equivalent dose rates due to neutrons and gamma at points 3 and 4 were measured while the reactor was critical at 340 W power.

Figure 2: The monitoring points (3 and 4) and J-9 channel position in the Argonaut reactor hall.



It was used the PSN 7013 detector sn 0094, calibrated on 05/06/2021, to measure the ambient equivalent dose rate for gamma-ray (γ), and the PNM200 detector sn 0074, calibrated on 11/08/2021 to measure the ambient dose equivalent rate for neutron (n). The monitors were positioned 1 meter above the floor. The measurements were taken while the plate chassis was positioned in front of the J-9 channel as shown in figure 2.

3. RESULTS AND DISCUSSIONS

The ICRP 103 [3] defined dose limit as the value of the effective dose or the equivalent dose to individuals from planned exposure situations that shall not be exceeded, meanwhile, the reference level represents the level of dose or risk, above which optimization of protection should be implemented, and its chosen value depends upon the prevailing circumstances of the exposure under consideration. So, reference correct level operations quantities must be used.

The ICRU 95 report presents the new factor measurement more representative of radiation risk possibility [7] and the relation between the ambient dose equivalent and personal dose equivalent. In this case, the ambient dose equivalent rate was used to estimate the personal dose equivalent received by the OEI, then it was compared with the reference level to the public.

The ambient dose equivalent rates for neutron and gamma measured in the point 3 and 4 are represented on Table 2.

Table 2 : Total ambient equivalent dose rates H*(10) for gamma and neutron measurements during the neutrongraphy plates adjust operations in the 3 and 4 points.

Point	γ (μSv/h)	n (μSv/h)	H*(10) (μSv/h)
3	3,0	0,5	3,5
4	100,0	127,6	227,6

The operational quantity for workplace monitoring H*(10) to personal monitoring $H_p(10)$ are related with the measurement form and have to be considering the radiation weight-factor w_R. For neutron emitted at Argonaut reactor the weight-factor is $w_R = 5$, because the range energy is less than 10 keV [1, 8]. For permanence time in the workplace, the occupancy factor is about 3 min, the personal equivalent dose can be estimated 0,04 mSv, using the equation 1.

$$H_p(10) = H^*(10)\ .\ w_R \qquad (1)$$

For neutron radiation the measure would be underrate. Because this, a correct factor of 1.4 is used. Considering the frequency this operation (neutrongraphy plate adjustment) be five times for month, the effective dose estimated is 0,25 mSv per month. If this work repeats 10 months per year, the annual effective dose equivalent $H_{(E)}$ is about 2,5 mSv, it would reach more than 150% to annual dose to MP, just for this operation (Table 3).

Table 3: Effective dose equivalent $H_{(E)}$ estimated for gamma and neutron in the points 3 and 4 during the operation.

Point	H_E (μSv/h)	Occupancy fator (f_o)	H_E x f_o (mSv)	H_E/month (mSv)	$H_{(E)}$/year (mSv)
3	6,5	0,05	0,0003	0,0016	0,02
4	993,2	0,05	0,0496	0,248	2,48

4. CONCLUSIONS

Young scientist trainees and scientific researcher trainees are submitted to the same radiation exposed than workers, therefore they must be considered as occupationally exposed individuals. However, as they do not have a formal employment relationship with Nuclear Engineering Institute, their radiological risks must be minimized more than workers. In this way, their effective dose optimizations must comply with the member of public' dose restrictions, observing the limits in special circumstances mentioned in the standard CNEN 3.01 (section 5.4.2.1, note c) [4]. For this, is important to include the young scientist trainees and scientific researchers at radiology monitoring program and to know the research period.

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CONFLICT OF INTEREST

All authors declare that they have no conflicts of interest.

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