BRAZILIAN JOURNAL
OF
RADIATION SCIENCES
11-01A (2023) | 01-10 | e2221

Radiometric survey in microscopy laboratory

Profeta[a], W. H. S.; Haubrich[a], O.; Ogihara[a], J. T.; Fontes[a], G. G. G.; Pereira[a], I. A. T.; de Azevedo[a], A. M.; Soares[a], J. B.; Andrade[a], E. R.; Cardoso[a], D. O.

[a] *Instituto Militar de Engenharia (IME) / Seção de Engenharia Nuclear (SE/07). Praça General Tibúrcio 80 – Urca, 22290-270, Rio de Janeiro - RJ - Brasil*

william.silva@ime.eb.br

ABSTRACT

The objective of this paper was the radiometric survey at the Materials Engineering Laboratory of the Military Institute of Engineering, in Rio de Janeiro, Brazil. Properties of materials are analyzed in this laboratory using X-rays machines. For the development of that work, two scintillator detectors were used with their associated electronics. Detector "A" has NaI(Tl) as scintillator material and detector "B" has $CeBr_3$. In addition to verifying whether the measured dose rate is in accordance with that provided by the CNEN standard, a comparison was made between the efficiencies of these radiation detection equipment.

Keywords: **X-Ray, Dosimetry, Radiation Protection.**

ISSN: 2319-0612
DOI: https://doi.org/10.15392/2319-0612.2023.2221
Submitted: 2022-11-30
Accepted: 2023-06-07

1. INTRODUCTION

In any environment where there is the presence of ionizing radiation, it is necessary to have studies and periodic verifications of this installation in order to guarantee the safety of operators and any individuals who use that space or specific equipment that emits radiation. In this sense, we can monitore a quantity like equivalent dose, that is the average absorbed dose in the organ or tissue [1] [7]. Therefore, the radiometric survey and subsequent evaluation is justified, since the investigated location has equipment that produces the physical agent under study.

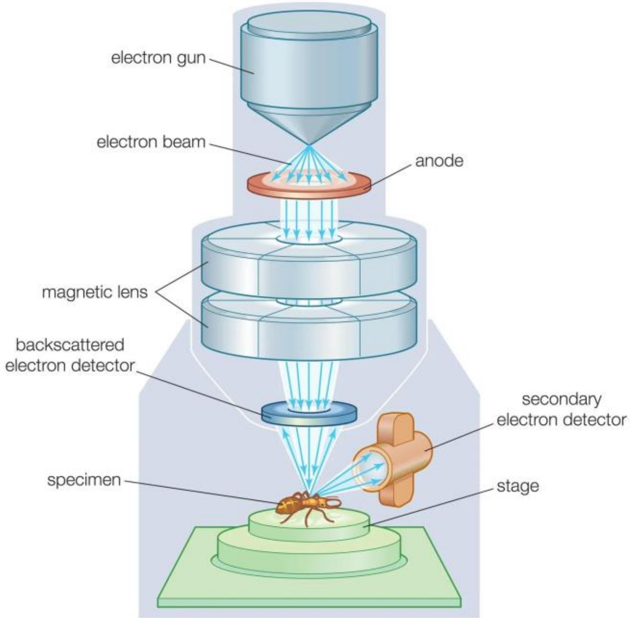
The present paper is characterized by the multidisciplinarity, passing through the areas of: i) Radiation Dosimetry, since it evaluates the dose rate received by the occupationally exposed individuals (OEI); ii) Radiological Protection, since it seeks to analyze the effectiveness of the shielding, by observing the secondary scattering in the equipment room and; iii) Military Area, the study search to add knowledge in the field of radiological and nuclear defense (RND) as well as nuclear instrumentation, as it allows to ascertain the best equipment for future acquisition by the armed forces. Thus, the scenario of analysis was the materials science laboratory of the Materials Engineering course (SE/8), at the Military Engineering Institute (IME), where activities such as the determination of chemical and morphological properties of samples are developed. For the practice of these measurements, equipment whose main operation occurs through the emission of ionizing radiation were emission, such as the energy dispersive x-ray detector (EDX) and the scanning electron microscope (SEM) with energy associated dispersion, hence the name (SEM-EDS).

SEM-EDS uses thermionic emission to scan the material. The operation of EDS is based on the interaction of accelerated electrons directed at a target to produce photons in the X-ray range, Bremsstrahlung or characteristic, which in turn reaches a given sample. Bremsstrahlung radiation occurs from the sudden deceleration of an energetic electron due to the attraction caused by the Coulomb field of the nucleus [9]. The emission of characteristic X-rays results from the transition of an electron from the outermost layer to one from an innermost layer when there is a vacancy caused by the collision of an accelerated electron with the bound electron in the innermost layer. This transition emits an X-ray photon that is characteristic of the material [2]. Therefore, the radiometric survey of the installation is of paramount importance to assess whether additional exposure occurs due to the operation of radiation emitting equipment. The analysis of this scenario, in the materials science laboratory, can be done by studying the spectra obtained and the dose rate shown by the scintillator detectors A (NaI) and B (CeBr3) (which will be better described in the topic *Materials and Methods*). Using these same data, it is possible to qualitatively compare the information between the two detectors used and evaluate which one has better sensitivity. In addition, it seeks to verify which dose the occupationally exposed individual (OEI) receives, assessing whether it is within the norms of CNEN [3]. It should be noted that the walls of the site are made of masonry and do not have radiation shielding.

2. MATERIALS AND METHODS

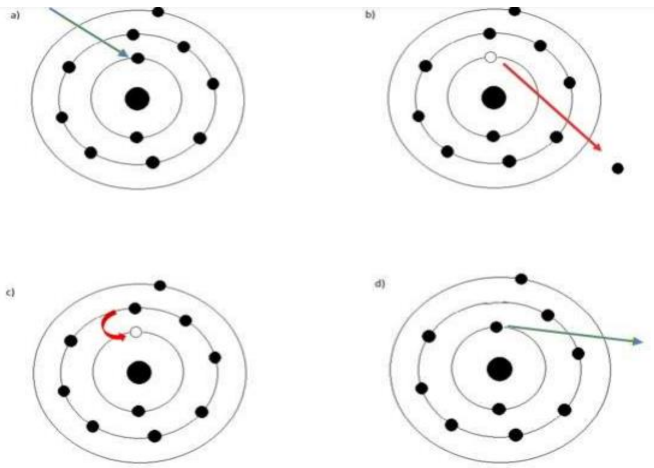
In order to ensure the accuracy of the results obtained, at each point of interest, four measurements were performed that could obtain the energy spectrum in the desired area. As mentioned above in the introduction, the Materials Engineering Laboratory (SE/8) generates X-rays in order to analyze samples of materials. These analyzes are performed using the SEM-EDS equipment and the EDX spectrometer, arranged in different rooms and separated by room 2, as shown in figure 3. The SEM - EDS has a filament, usually made of tungsten, which is subjected to a potential difference that heats it up and causes it to release electrons. These electrons are accelerated by this potential difference and are directed to fall on the sample of interest. As is known, this interaction between electrons and materials results in different types of energy emissions, according to each analyzed material, which are interpreted by imaging equipment, as shown in Figures 1 and 2. Among the emissions, some occur in X-ray range produced by electrons Bremsstrahlung. It is also necessary to point out that the maximum electron acceleration potential for the SEM-EDS is 30 kV and 200 nA, while for the EDX spectrometer it is 50 kV and 3mA.

Figure 1: Scanning electron microscope



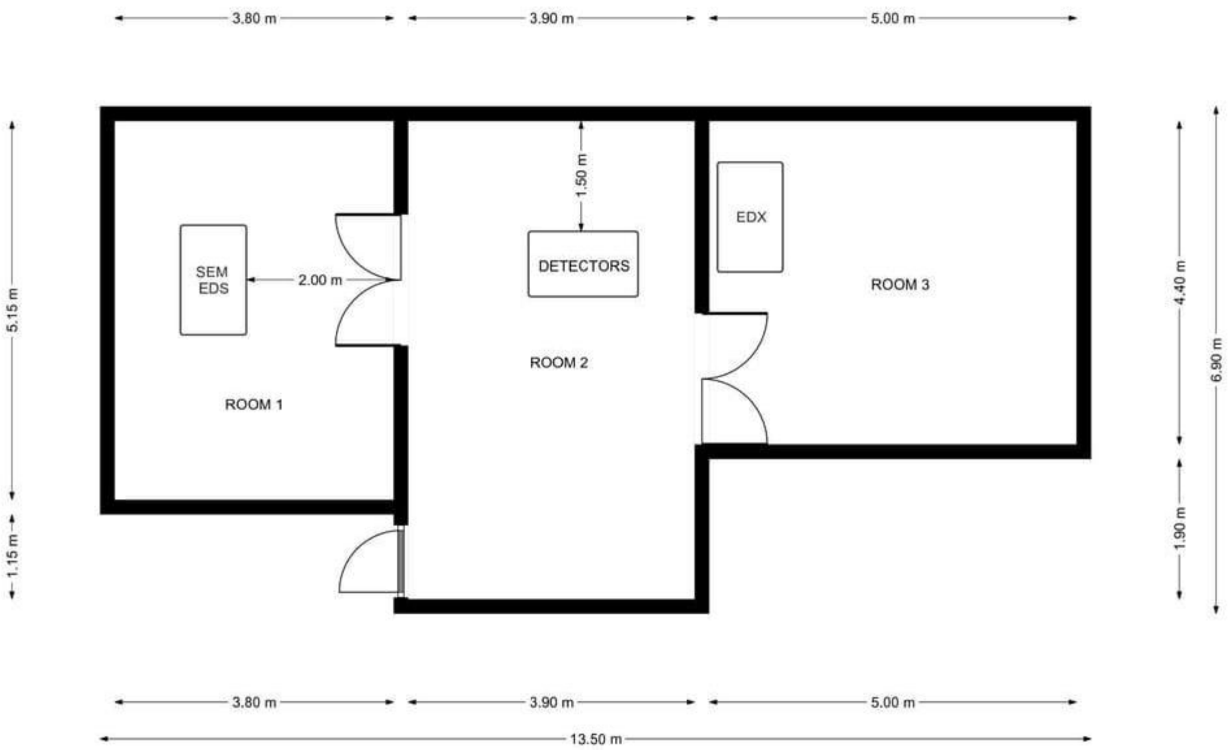
Source: Encyclopaedia Britannica, 2012.

Figure 2: Scheme of an atomic structure emitting X-ray energy due to electronic transition:(a) electron beam bombardment; (b) ejection of the inner shell electron; (c) electronic transition; (d) emission of characteristic X-ray energy.



Source: Stephani *et al*, 2021.

Figure 3: Arrangement of Monitoroints in the Laboratory



The radiometric survey of the laboratory began with the background measurement, in other words, the two aforementioned equipment turned off. Subsequently, based on the conservative aspect of the evaluation, that is, the scenario with the worst possible view generating the worst consequences, which is the environment with the highest occupancy factor and exposed to radiation from both connected equipment, the measurements were performed in room 2, as shown in Figure 1.

The equipment used to measure the dose rate consisted of two detectors A and B, in which the following characteristics of the models stand out:

1. Detector A: NaI 3” x 1.5”, with operating range for photons with energy between 25 keV to 3 MeV.
2. Detector B: CeBr3 2” x 1”, with operating range for photons with energy between 11 keV and 3 MeV.

3. RESULTS AND DISCUSSION

The Figures below provides the background spectra obtained by detectors A and B and the net spectra for a situation in which the SEM-EDS and EDX equipment were operated simultaneously, since conservatism was looked for in the measurements. It is worth mentioning that the net spectrum was produced by discounting the background radiation measurement, which allows a better visualization of the information.

Figure 4: Background spectrum of detector A.

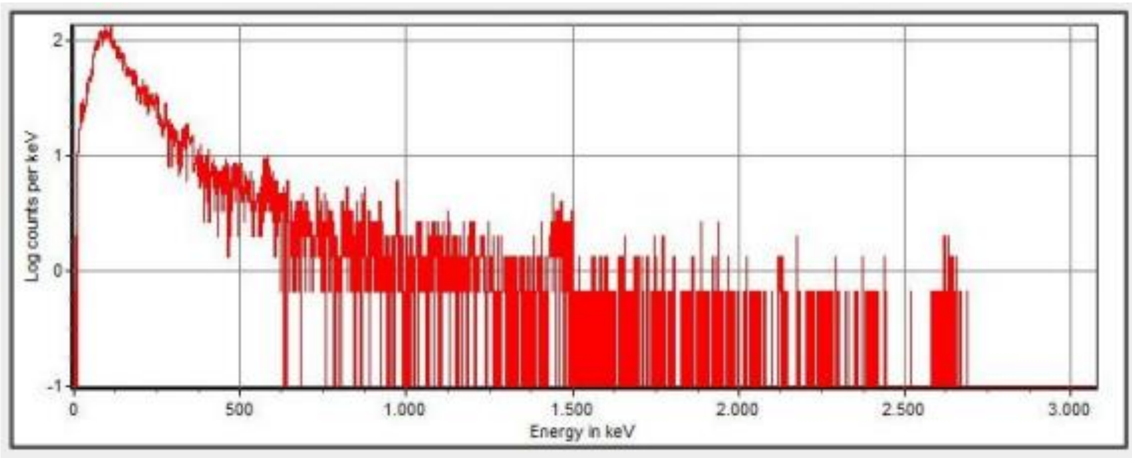


Figure 5: Background spectrum of detector B.

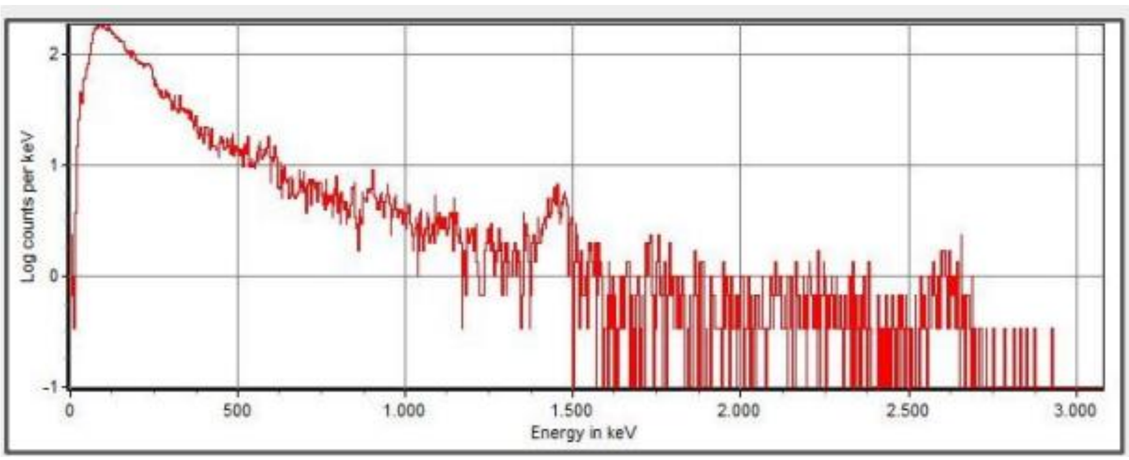


Figure 6: Net spectrum obtained by means of detector A for both equipment in operation.

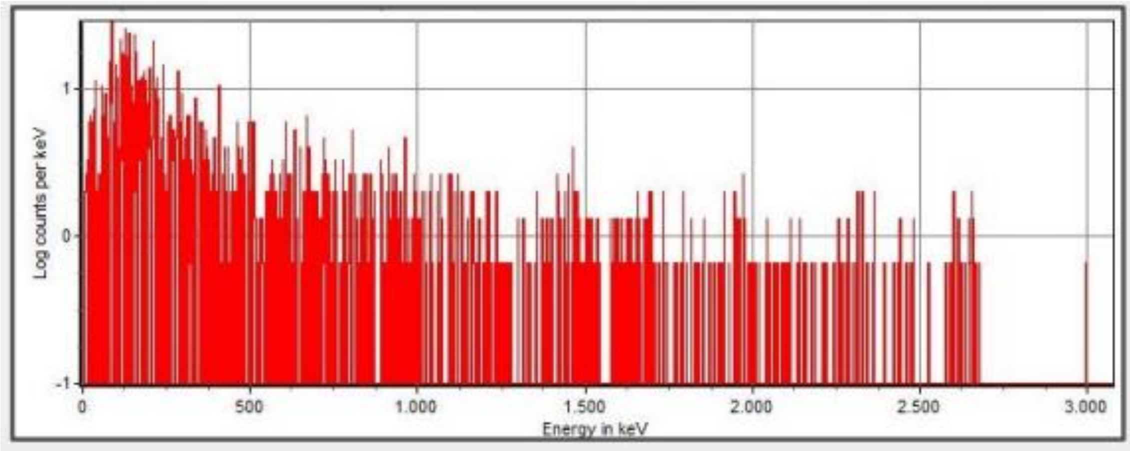
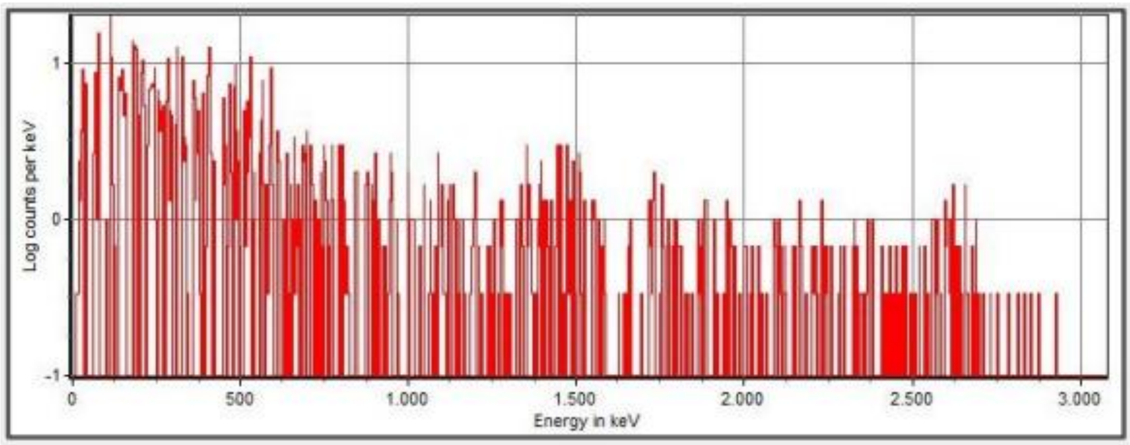


Figure 7: Net spectrum obtained by means of detector B for both equipment in operation.



It can be seen in the figures that there is a peak at the beginning of the spectrum where there is an abrupt and substantial increase in particle counts. There is the presence of a characteristic peak, whose center is around 1460 keV, which is the energy contained in gamma radiation emission by the radioisotope potassium-40 (K-40) [5]. Such spectrographic behavior can be extracted from the residual radiation as expected or by the large grouping of people in the laboratory environment since there is the presence of this element in the human body.

Table 1: Primary Annual Effective Dose Limits

QUANTITY		**Occupationally Exposed Individual (mSv)**	**Audience Individual (mSv)**	**Apprentice or Student (16 to 18 years old) (mSv)**	**Visitor or Companion (mSv)**
Effective Dose or Whole Body Dose		20	1	6	5
Equivalent dose	lens of the eye	150	15	50	-
	Extremities (hands and feet) Skin	500	50	150	-

Source: CNEN-NN-3.01 (2011).

The equipment used has output data in spectra, as seen previously, as well as provides the dose rate in the environment, in microsievert/hour. The dose rate returned by the meter when the analyzed equipment was operating did not exceed the background of the site, around 0.12 microsievert/ hour.

The equipment works by firing electrons accelerated by a difference in electrical potential, occurring on a nanosecond scale. Thus, the emission of radiation as a result of these shots is recorded by means of characteristic peaks as shown in figures 4, 5, 6 and 7. It should be noted that exposure to OEI in the laboratory is parameterized by the time the laboratory is occupied, which consists of a period eight hours a day, five days a week, totaling forty hours a week. The daily working regime of the equipment varies according to the demands of the laboratory and it is important to mention that it does not operate uninterruptedly. Therefore, there was an investigation in the first eighty seconds between activating the equipment, with the production of the energy peak registered by the detector, and the return of the energy levels to the background of the room. Thus, it was possible to see that the maximum exposure time is less than one second. When we compare the working regime of the microscopes with the exposure time of the laboratory workers, it can be inferred that the sum of the shots fired as well as the radiation emitted by them are much lower than the dose rate limit allowed by the work of the OEIs (table 1). It should be noted that the operators have an individual dosimeter and are periodically referred for laboratory analysis.

Regarding the equipment, detector A that uses NaI as a scintillator crystal showed greater efficiency, as expected because its average atomic number is higher compared to other scintillator materials. However, detector B, which uses cerium bromide, despite being less efficient, offered higher resolution in the spectrum survey, as shown in figures 5 and 7 [8] [10].

4. CONCLUSIONS

Given the above, it should be noted that the radiometric survey carried out at the premises of the aforementioned laboratory detected only background radiation and gamma rays from the K-40 present [1]. The net spectrum refers to the intrinsic noise of the detector. As such, there is no additional exposure contribution to OEIs. However, it is considered pertinent to carry out a new survey with a longer detection time, in order to remove doubts about the sensitivity of the detectors and the contribution of the additional exposure caused by the spectroscopy equipment.

Comparing the OIE work regime with the microscopy equipment emission regime, as well as Table 1, it is possible to consider that the dose received by the individual in the laboratory does not pose a risk to his health, since a visual analysis of the spectra is performed. net and background, there is great similarity between their respective values. Knowing that the dose rate is the energy transmitted to the medium and comparing the spectra, it is inferred that the dose rate does not change significantly when the equipment is used.

As for the detection equipment, it is possible to infer that the best instrument will depend on the intended use. In practice, based on a military action for emergency remediation of a situation of radiological and nuclear contamination, we can infer that if the purpose is to determine the dose rate, since it is necessary to know, in quantitative terms, whether the evaluated area is safe or not and, if not safe, knowing which personal protective equipment (IPE) is most appropriate to use as well as knowing which evacuation and mitigation actions to choose, the use of detector A is recommended. However, if the intention is to identify the contaminating radionuclide, detector B is recommended, as it ensures greater reliability in terms of spectrum resolution.

ACKNOWLEDGMENT

We would like to thank the Military Engineering Institute (IME) which, together with the great efforts of the then head of section Professor Avelino dos Santos and the course coordinator Wallace Vallory Nunes, provided us with the means to carry out all stages of the experiment when participating in the Radio 2022 event with the aim of show all the knowledge gained from the study.

REFERENCES

[1] ANDERSON, E. C., & LANGHAM, W. H. (1959). **Average Potassium Concentration of the Human Body as a Function of Age**. Science, 130(3377), 713–714.

[2] ATTIX, F. H. Introduction to Radiological Physics and Radiation. Ed. Wiley-Vch, 1a Edição, 1991.

[3] CNEN-NN-3.05 Diretrizes Básicas de proteção radiológica, Comissão Nacional de Energia Nuclear, Rio de Janeiro, 2005.

[4] CNEN-NN-3.01 Diretrizes Básicas de proteção radiológica, Comissão Nacional de Energia Nuclear, Rio de Janeiro, 2014.

[5] NUCLÉIDE, Lara. **Library for gamma and alpha emissions**. Disponível em: <http://www.lnhb.fr/Laraweb/>. Last accessed: 30 March 2023.

[6] JOY, David C. , FORD, Brian J. and BRADBURY, S. **Scanning Electron Microscope**. Encyclopedia Britannica, 2023. Avaible at: https://www.britannica.com/technology/scanning-electron-microscopeanning-electron-microscope. Last accessed: 24 April 2023.

[7] OKUNO, E; YOSHIMURA, E. **Física Das Radiações**. São Paulo: Oficina de Textos, 2010.

[8] PRICE, William J. **Nuclear Radiation Detection**. Nova Iorque: McGraw-Hill Book Company, 1958. 382 p.

[9] SARON, E.S.; SOARES, B.M.C. **Microanálise elementar de materiais: Aplicações do sistema MEV-EDX**. CETEA INFORMATIVO: Boletim de tecnogia e desenvolvimento de embalagens. Vila Nova - Campinas, Vol. 22, n° 1, p. 1-4, janeiro de 2010.

[10] TAUHATA, Luiz *et al*. **Radioproteção e Dosimetria**: Fundamentos. 9. ed. rev. Rio de Janeiro: IRD/CNEN, 2013. 345 p.