Low-Energy X-Ray Dosimetry Using a Parallel Plate Chamber and Fricke Gel

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INTRODUCTION

Low-energy X-ray radiation plays a key role in several nuclear applications, ranging from medical analysis, such as X-ray Fluorescence (XRF) for blood analysis, to diagnostic imaging, such as mammography, computed tomography, to therapeutic applications, such as Intraoperative Radiotherapy (IORT) using electronic brachytherapy for cancer treatment [1, 2].

It is essential to know the exact dose administered to the patient in order to minimize the undesirable effects of radiation. To this end, it is essential to apply the main concepts of metrology in ionizing radiation, ensuring reliable measurements through the use of duly calibrated dosimeters and tracked to national and international metrological networks.

The present work has the general objective of comparing 3D dosimetry with the results obtained through the use of parallel plate ionization chambers, in addition to performing dosimetry of systems that use low-energy beams.

Figure 1 - (A) FXG gel irradiation setup in low energy beams (B) Dosimetry setup with Parallel Plate Ionization Chamber.

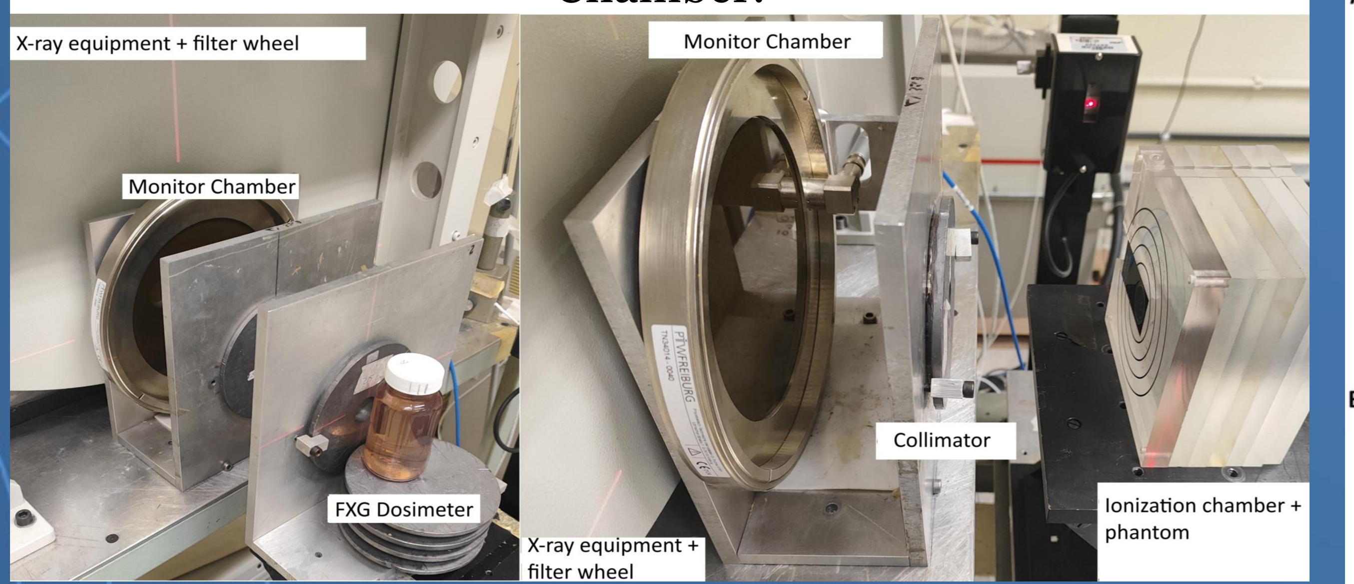
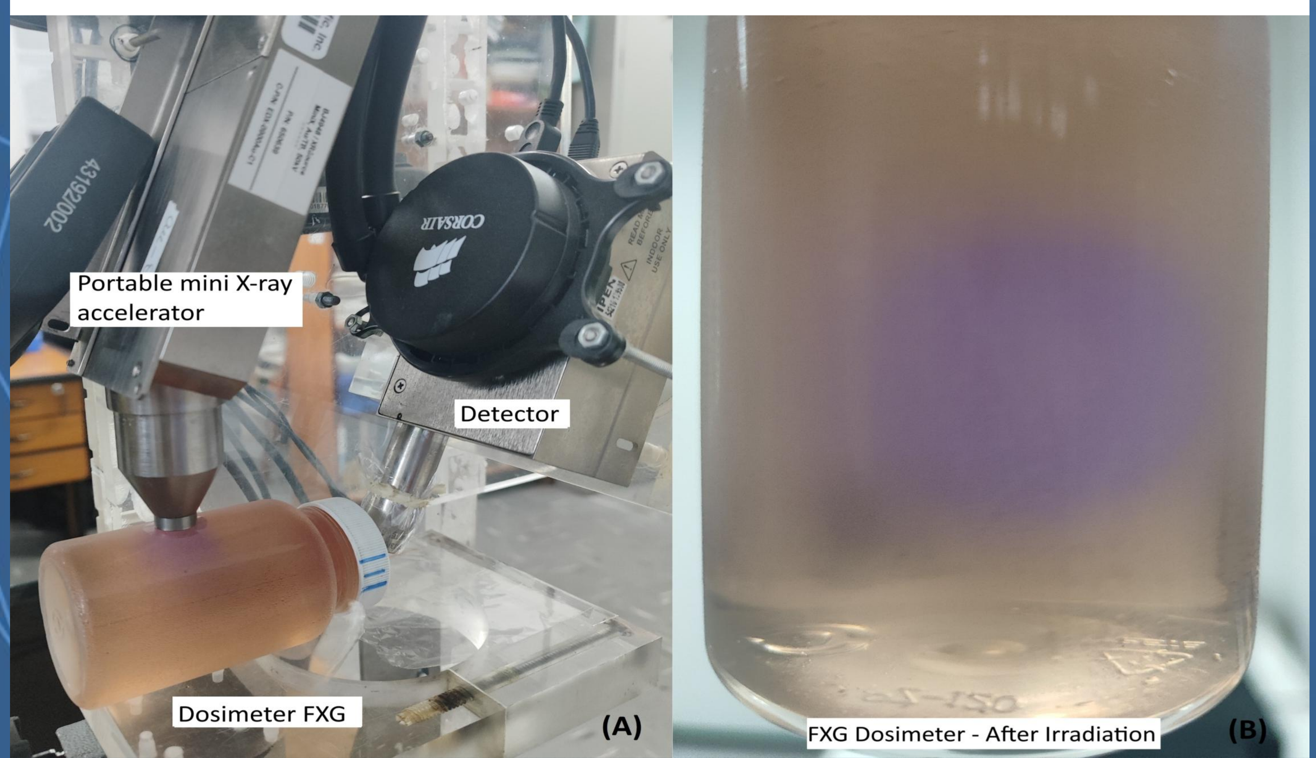


Figure 2 - (A) Setup for FXG irradiation in pFRX. (B) FXG after irradiation



METHODS AND MATERIALS

Low-energy X-ray beam dosimetry was performed using a Pantak Seifert industrial X-ray equipment and a portable Amptek® X-ray fluorescence equipment with a gold target. In both configurations, parallel plate ionization chambers, PTW, model 23342, calibrated in the quantity absorbed dose in water and the Fricke Xylenol Gel (FXG) dosimeter were used.In the Pantak Seifert equipment, the measurements were conducted following the TRS 398 formalism for determining the absorbed dose in water, in the reference quality T-50 (b) and at a distance of 50 cm from the equipment focus. FXG dosimeter were subsequently irradiated in this equipment under the same conditions, with doses of 3 Gy and 5 Gy. Irradiations using portable X-ray fluorescence (pXRF) equipment were conducted as close as possible to the beam exit, with a voltage of 50 kV and a current of 200 µA for both dosimeters. Optical Computed Tomography (OCT) was used to analyze the distribution of absorbed dose in FXG solutions. This three-dimensional imaging technique is based on the reconstruction of cross-sectional images obtained by detecting the attenuation of light beams when they interact with the sample.

Figure 3 - FXG Dose Map in T-50 Quality. (A) Dose of 3 Gy; (B) Dose of 5 Gy.

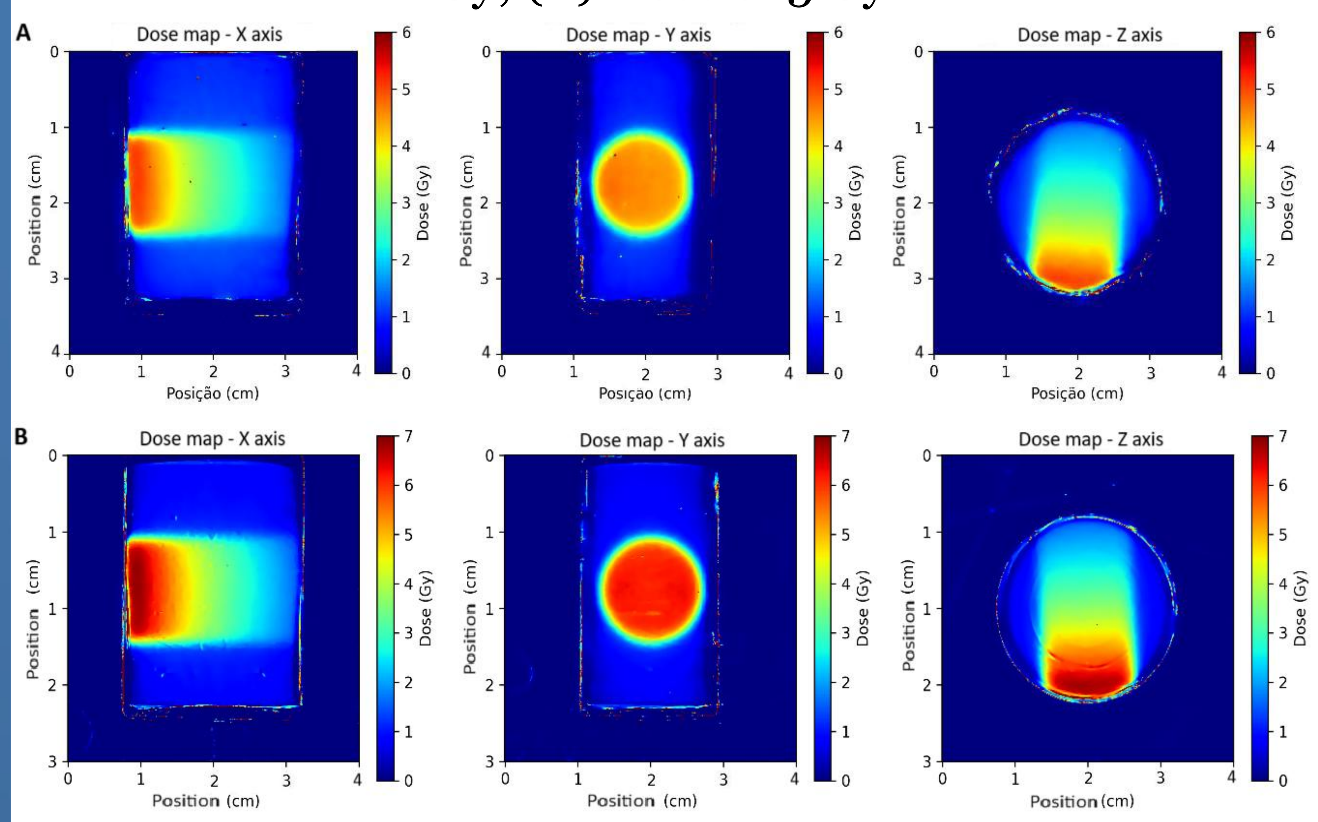
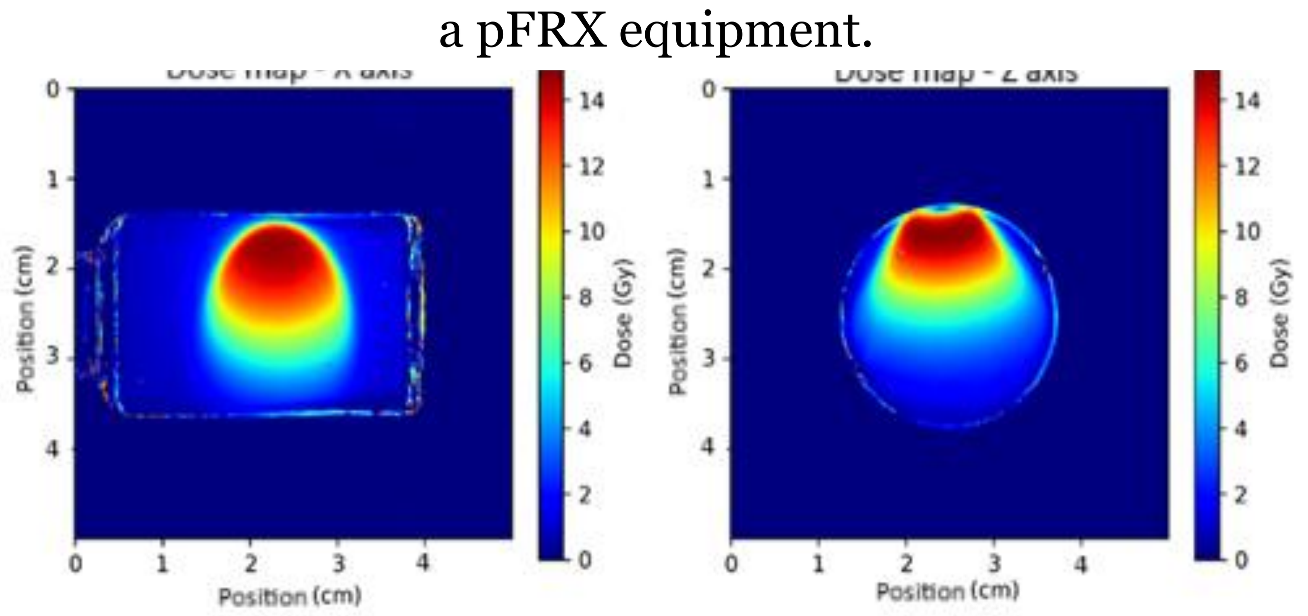


Figure 4 - Dose \Map of FXG exposed to X-radiation by a pFRX equipment.



RESULTS AND DISCUSSION

The measurement values showed good agreement for both dosimeters for the doses worked. Using the FXG, a 3D dose map was obtained where it was possible to see expected characteristics for low-energy X-ray beams, which tend to deposit most of the energy close to the surface, and which, due to the interaction of the radiation with the matter, obtain a maximum dose, and which has a significant reduction in the dose in a few cm. In addition, with the production of secondary electrons, the maximum dose obtained after a few cm in the irradiation of 3 Gy, reached 5.4 Gy (Figure 3) and in the irradiation with 5 Gy, a maximum of 6.8 Gy (Figure 3) was obtained. The dosimetry for the X-ray fluorescence equipment shows a well-defined area of higher dose and a dose gradient that decreases progressively with depth, indicating the behavior of low-energy beams (Figure 4). These results highlight the potential of the FXG as a three-dimensional dosimeter in applications such as INTRABEAM and low-energy beam dose distribution studies.

CONCLUSIONS

The results highlight the potential of combining dosimetry using parallel plate ionization chambers and, together with FXG as a three-dimensional dosimeter in applications, for example in IORT, and dose distribution studies in low-energy X-ray beams.

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