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Linearity and reproducibility response of Fricke dosimetry for low energy X-Ray beam

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Abstract: The Fricke dosimeter is the most used, liquid chemical dosimeter. It has been shown to be a feasible option for the absorbed dose standard. The present work aims to determinate a dose-response curve of Fricke solution using different doses and reproducibility test comparing the calculated dose to Fricke solution and Ionizing Chamber. Tests were performed using an X-ray irradiator for biological research at Radiological Science Laboratory (LCR/UERJ). The results showed a linear response to different doses of type A uncertainties from 0.08 to 1.2%. Reproducibility test showed type A uncertainties of 0.16% to the dosimeter.

Keywords: Fricke dosimeter; Linearity; Dose response curve; Reproducibility.

1. INTRODUCTION

Chemical dosimetry using a standard $FeSO_4$ solution has been shown potential to be a reliable standard of absorbed dose.

However, the linearity for this dosimeter and reproducibility tests are currently not available. Even though the measurements of Fricke dosimetry show a good linearity, its methodology requires a lot of attention and care. Organic or inorganic impurities into the dosimeter can change the response of the solution.

In order to obtain lower uncertainties in the dose measurement, it is necessary to eliminate all the possibilities of influence on the solution that are not related to the ionizing radiation. Repeatability and reproducibility tests can be used to find and discuss those influences and to provide greater security and accuracy for the results.

Controlled temperature, pressure and humidity are crucial to perform the tests. Few authors have shown a dose-response curve using different qualities comparing absorbance and dose or Fricke dose and the dose calculated through other methods [1-3].

This work aims to evaluate the Fricke solution stability and linearity through the dose-response curve and reproducibility. The obtained results will be compared with the ionizing chamber response, the most used dosimeter, according to the literature. We expected to develop and implement a standard for the absorbed dose in water based on the Fricke chemical dosimetry; and also the use this methodology for different energy dosimetry used for research.

2. MATERIALS AND METHODS

For the process of irradiation, the Fricke solution was disposed into a bag and it was put individually in an acrylic holder for their total irradiation. The irradiation was performed using an X-Ray irradiator for biological research, completely self-shielded (RS 2000X, Radsource, CA, USA), at the Radiological Science Laboratory (LCR/UERJ), Rio de Janeiro, Brazil. The figure 1 shows the acrylic holder to bag (holder 1), ionizing chamber (holder 2) and another holder that was not used in this work (holder 3). Figure 2 shows the complete setup into the X-Ray irradiator.

In this paper the range to dose to water used was according with the literature from 14 to 40 Gy [2,4].

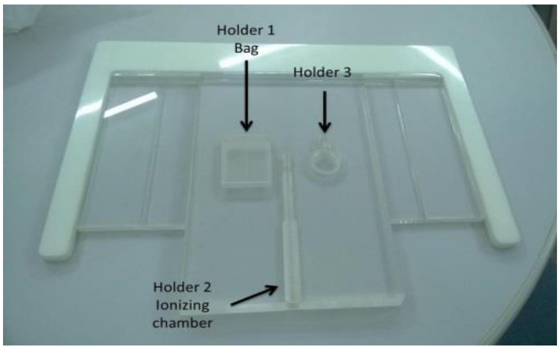

Figure 1. Acrylic experimental design.

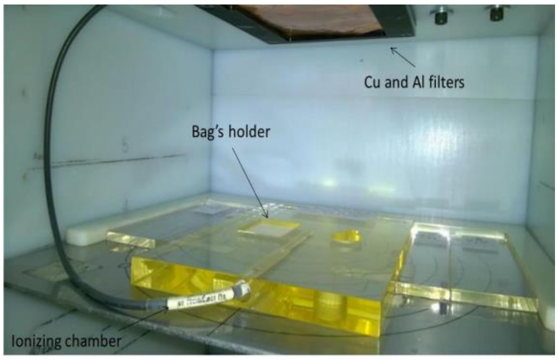

Figure 2. Irradiation Setup for Bags containing Fricke solution and ionizing chamber.

Cu (0,32 mm) and Al (1,75 mm) filters were used taking into account a half value layer HVL of 0,66 mmCu. The HVL was calculated using a X-Ray source (IRD-Brazil) considering an effective energy of 68 KeV.

2.1. Linearity study

The electron accelerating voltage used on the X-ray tube for the linearity study was 150 kV and different doses were tested.

The dose-response curves were obtained changing the current and maintaining the time of irradiation, and after, maintaining the current and changing the time, ranging from 7 to 46 Gy for both tests.

During the irradiation, another bag containing Fricke solution was kept at the same room of the irradiator to be used as a control solution. Control and irradiated solutions had their absorbance read using a Varian cary 50 Bio spectrophotometer.

The absorbed dose to Fricke solution (D_F) was calculated through the equation (1) [6-7].

$$D_F = \frac{\Delta OD}{G(Fe^{3+})\cdot l \cdot \rho \cdot \varepsilon} \quad (1)$$

Where, ΔOD is defined as the optical density (OD) at 304 nm, taking into account the temperature effect, G(Fe3+) is the radiation chemical yield of the ferric ions for 150 kV, previously calculated by our group ($1.447\cdot10^{-6}$ $mol\cdot J^{-1}$) using the parameters described in the methodology, l is the optical path length of the cuvette (1 cm), ρ is the density of the Fricke solution ($1.024\ g\cdot cm^{-3}$) at 25°C and ε is the value for the molar linear absorption coefficient for ferric ions (equal to 2174 M^{-1} $cm^{-}1$ at 304 nm, which is numerically equal to the value that was used previously [4,7].

The Absorbed dose to water D_W measured with ionizing chamber NE2571 was calculated using the equation (2) according to TRS 277 [9].

$$D_w = M_u \cdot N_{D,w} \quad (2)$$

M_u is the charge collected by ionizing chamber after the correction to pressure and temperature and $N_{D,w}$ is the calibration factor in terms of absorbed dose to water [8,9].

3. RESULTS

3.1. Linearity

The figure 3 shows the linearity response of the chemical dosimeter when the current was increased. The figure 4 shows the same response when the time of exposure was increased. Linear regression showed a R-squared of 0.999 for both cases.

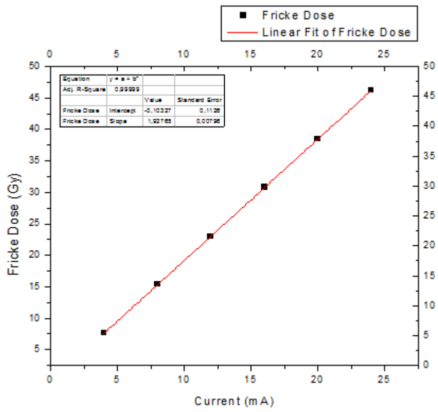

Figure 3. Dose response curve changing the current.

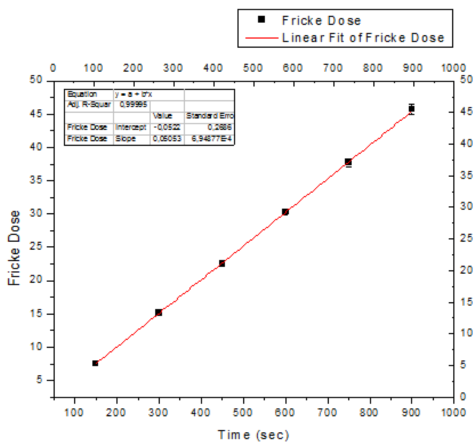

Figure 4. Dose response curve changing the time.

The range of the doses corresponding to different times and/or current was from 7 to 40 Gy. The doses to Fricke solution were calculated using the equation (1).

The Ionizing chamber was used as a monitor dosimeter and the dose to water was calculated by equation (2).

It is important to note that to the repeatability measures, the type A uncertainties were 1.2 % at most, to doses under 15 Gy. On the other hand, the doses from 15 to 46 Gy, showed type A uncertainties from 0.08 to 0.3%.

3.2. Reproducibility

The figure 5 shows a stability of the measurements during the days of repetition.

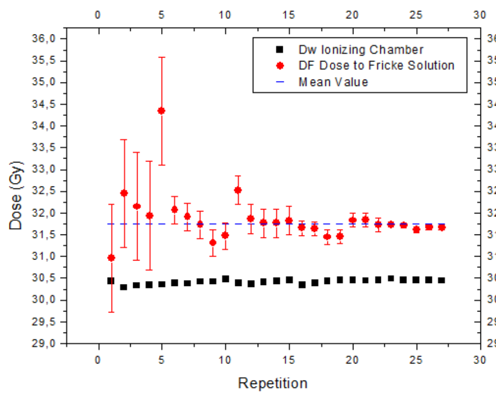

Figure 5. Graphic of stability during different days of measurements.

The stability measurements showed that on the first 5 repetitions the standard deviation was higher than the others. It could have happened due to the position of the ionizing chamber or other geometry factors that could have influenced the experiment, and this was corrected at the 6th measurement.

The dispersion of values in relation to the mean to dose of Fricke solution was 0.7% disregarding the first five measures. The results showed type A uncertainties to dose to Fricke solution of 0.16%.

The absorbed dose to water calculated through dose of Fricke solution can be obtained calculating some Monte Carlo correction factors. It was not considered in this paper, but open opportunities for the future.

4. CONCLUSIONS

The absorbed doses derived from Fricke Solution measurements show that the chemical dosimeter response is linear with R-squared of 0.999. Repeatability showed uncertainties lower than 0.3%.

This study can open new opportunities to use the Fricke dosimetry as an alternative method to be a feasible option for the absorbed dose to water.

5. ACKNOWLEDGEMENTS

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