Introduction

Low energy X-ray radiation produced by X-ray tubes is used in many different medical procedures. However, in each case, the cells of the human body absorb a certain dose of radiation. For this reason, it is important to study the lesions created in the cells after irradiation. The methods used in radiobiology are helpful for this purpose. However, the study of radiation effects requires the construction of various experimental systems with the possibility of irradiating live cells. This kind of experimental setup was built at the Jan Kochanowski University in Kielce, Poland.

Experimental setup

The components of experimental system are:

- X-ray Diffraction C-tech tube with molybden target (Mo) and Long Fine Focus (XRD C-Tech Tube Mo with LFF. no. 9430 922 00291, PANalytical, Holland).
- generator PW3830 (PANalytical, Holland).
- a set of filters made of: zirconium (Zr), vanadium (V), iron (Fe), nickel (Ni) included in a cover of the tube (PANalytical, Holland).
- aluminum (Al) filters.
- measurement station positioned inside an irradiation chamber and containing Petri dish holder situated on rotating arm of electronically controlled robot (no. 7R150 with stepping motor: 8SMC1-USBhF and graphical interface: SMCView, Standa, Lithuania).
- radiation shielding.

Fig.1 shows schema of an experimental setup.

Dosimetry and survival curve

The dosimetry was done using Gafchromic EBT2 and XR-RV3 films (Ashland Advanced Materials, USA) which were calibrated in Secondary Standards Laboratory, Łódź, Poland using a plane ionization chamber TM77334 (PTW, Germany). The EBT2 films were situated in different places of experimental setup marked from a) to l) (see Table 1). The survival curve for CHO-K1 cells was measured (see Fig.2).

Distribution of absorbed dose

Profiles of X-ray beams (Fig.3) were registered with help of Gafchromic EBT2 films which were placed inside Petri dish filled with air and irradiated in two fractions. After first fraction, the Petri dish was rotated at angle of 180°. The rotation procedure is necessary to eliminate strong non-homogeneous X-ray distribution in the vertical direction. The y and z profiles correspond to the horizontal and vertical intersections of the beam surface (typical data on Fig.3).

Monte Carlo simulations

The Monte Carlo (MC) code Fluka was used to model X-ray distribution in the new experimental set up (Fig.1). The aim of performed simulations was to calculate dose rate distribution (Fig.4) and dose rate profiles in the region of Petri dish with CHO-K1 cells (Fig.5).

Fig. 3. The profiles of X-ray beam calculated using irradiated EBT2 film placed inside Petri dish filled with air and was rotated.

Fig. 4. 2D distribution of dose equivalent rate calculated for the experimental set up in the XZ plane (left side) and in the YZ plane (right side).

Fig. 5. 2D distribution of dose rate calculated in the Petri dish area (left side), horizontal (in the middle) and vertical (right side) dose rate profiles in the 12.9 μm of Petri dish thickness.

Dose rate calculated by Fluka code in the irradiated region between 2 cm and -2 cm in horizontal and vertical axes is in a good agreement with the measurements (see Fig.5 and Table 1 part f)).

The dose rate in the cell region from 1.2 cm to 1.2 cm in horizontal coordinate, close to borosilicate coverglass is at level 0.89 Gy/min (Fig.5) and outside this region is at level 0.69 Gy/min. This 28 % dose rate increasing in the cells layer region is associated with the influence of additional irradiation indicated inside bottom of borosilicate coverglass (Fig.6).