Establishment of X-Ray Irradiation Factors for The Stabilipan

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X-Ray조사장치 Stabilipan의 照射條件設定

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Summary

The X-ray irradiation factors such as geometrical exposure conditions, voltage and current levels of X-ray generator installed at Applied Radioisotope Research Institute of Cheju National University were studied. The dose rates of X-ray irradiation were determined by the ferrous sulpate dosimetry, thermoluminescence dosimetry and X-ray film method.

Spatial distribution of X-ray irradiation is as shown in Figure 1 ; circular shapes with diameters of 13.2cm (area A), 19.8cm (area B) and 27cm (area C) at the distances of 16.3cm, 32.6cm and 48.9cm from the top of the irradiation chamber, respectively.

The equations for estimating dose rate depending on three factors(voltage, current and distance) were given from this study. One of the most usabel dose rate is about 1000 rads at 190kV and 12mA on the area A when irradiated for 5 minutes.

Introduction

The Stabilipan, a X-ray generator manufactured by SIEMEN, was installed in the Applied Radioisotopes Research Institute,Cheju National University. Apart from educational purposes, the Stabilipan is also used in radiation chemical and radiobiological researches. A rectangular irradiation chamber is connected to the X-ray tube, as shown in Fig. 1. In practice, it is operated at 190kV, 12mA which gives the intensity of X-ray about 200 rads per minute at the center of area A. Accurate and reliable dosimetry, that is, the precise knowledge of the dose or dose rate level at an irradiation position, is the most essential condition for the application of irradiation in every field. The important factors which can influence the dose rate of X-ray irradiation are voltage and current of X-ray tube as well as the exposure geometry.

The purpose of this study was to establish the X-ray irradiation factors by investigating the effect of three physical factors upon the dose rate. The experiments were performed by using ferrous sulphate dosimetry and thermoluminescence dosimetry. The results concerning geometrical condition of irradiation area were obtalined by X-ray film dosimetry.

Materials and Methods

Ferrous sulphate dosimeter

The principle of ferrous sulphate dosimeter or Fricke dosimeter is oxidation of ferrous ions in acidic, aerate, solution by radiation[2]. The dosimetry solution which consisted of 0.001M in ferrous ammonium sulphate, 0.001M in sodium chloride and 0.8N in sulfuric acid, was prepared by dissolving 0.392gm of ferrous ammonium sulphate and 0.058gm of sodium chloride in 1 litre of 0.8N sulfuric acid.

When Fricke dosimeter is irradiated, ferrous ions are oxidized to ferric ions. The number of ions oxidized is directly related to the absorbed energy due to X-ray irradiation. The spectrophotometer, Perkin Elmer Model Lamda 3, was used to determine the ferric ion concentration by measuring the ferric ion absorption change at the 305nm, 20℃. The absorbed dose was calculated by(4) :

$$D = \frac{A.\ N.\ b}{d.\ e.\ G.\ l.\ k[1+0.007(t-25)]}$$

where A = change in absorbance at 305nm
N = 6.022×10^{23} molecule/mole
d = density of dosimeter solution
= $1.024 gm/cm^3$
G = radiation yield of chemical substance
= 0.156/ev
l = optical path length
= 1cm
k = volume conversion factor
= $1000cm^3$
b = energy conversion factor
= 1.602×10^{-14} rad.gm/eV
e = molar extinction coefficient at 305nm, 25℃
= 2195 $l\cdot mol^{-1}\cdot cm^{-1}$
t = temperature of measurement.

Thermoluminescence dosimetry

Thermoluminescence dosimetry(TLD) has been found wide acceptance for measurement in beam of gamma ray and X-ray[1]. When thermoluminescent phosphor is exposed to ionizing radiation, many of freed electron become trapped in lattice imperfection in the crystalline solid. If temperature is raised, the electrons will be released from the traps and return to stable energy state with emission of light. TLD reader, consisting of heating element and photomultiplier system, is used to measure the emitted light which is proportional to the radiation dose.

The dosimeter material used in the experiment was lithium fluoride, teflon discs, 12.5mm diameter by 0.4mm thick, supplied by Isotope Teledyne Inc. The dosimeters were annealed for 6hrs. at 300℃ followed by 24hrs. at 80℃ to release the shallow trapped electron. They were read out on a Teledyne Model 7300 under nitrogen atmosphere. The integrated area response was measured by heating up to 285℃.

Calibration of thermoluminescence response has been made by irradiating lithium fluoride dosimeters of the same batch with gamma source at three levels ; 500R, 1000R and 2000R. The calibration and experimental dosimeters were read out at the same condition.

Film dosimetry

Because of their advantages, low cost, portability and permanent record, film dosimetry has been used in various fields[3]. In order to determine the geometrical condition of irradiation, X-ray film dosimetry was introduced. After exposure, X-ray films, Cronex 4, Dupont Inc., were developed by automatic developer machine, SAKURA 1X-130, using X-DOL-90 developer solution at 38℃ for 3 mins. The nonexcited grains were washed out by X-FIX-90 fixer solution at 40℃ for 30 secs.

Statistical procedure

Analysis of varience tested the effect of three physical factors and indicated whether there were an interaction effect. The estimated dose rate equations were calculated by least-square method and by factorial coefficient method.

Results and Discussion

1. Geometrical condition of X-ray irradiation

X-ray films were exposed at three distances from the X-ray tube, 16.3cm, 32.6cm and 48.9cm. The three developed films showed the circular surface area A, B and C (Fig. 1) that were blackened by uniform absorption of X-ray energy. The diameters of area A, B and C were 16.4cm, 24.7cm and 33.1cm, respectively. The

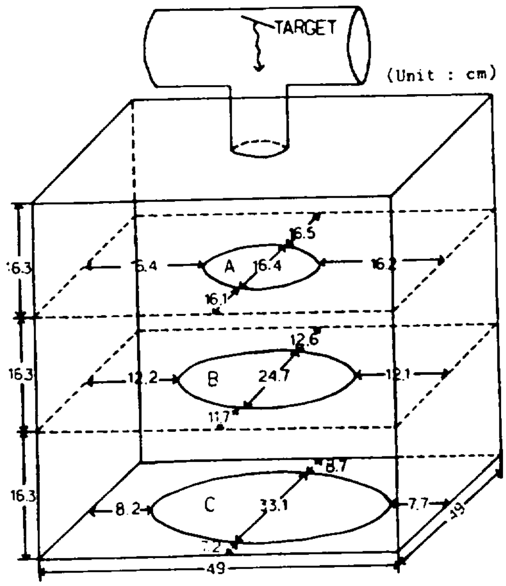

Fig. 1. Dimensions of the X-ray irradiation chamber and geometrical positions of surface areas exposured by X-ray beam at three different distances from the source.

film expoured at 16.3cm distance gave the sharp image while the film exposured at the bottom of the chamber appeared high foggy. That fact indicated that there was high scattering at the bottom of the chamber.

2. The uniformity of X-ray intensity

In order to check the uniformity of X-ray intensity, Fricke dosimeters were placed on the circumferences of area A, B and C. It was found that there were highly significant differences among the dose rate depending on the different positions of each circumference. But when dose rate were measured inner side of circumferences, the uniformity was improved very much ; no significant differences among the measuring sites. From this experiment we found that the diameters of area A, B and C, having the uniformity of X-ray intensity, were reduced to 13.2cm, 19.8cm and 27cm, respectively.

3. Influence of voltage and current of X-ray tube

The 4×4 factorial experiment was designed to study the effect of voltage and current of X-ray tube. Fricke solutions were irradiated under X-ray beam of 130, 150, 170 and 190kV. at 10, 12, 14 and 16mA, while the position of Fricke dosimeters were kept constant. It was found that both voltage and current were quantitative factors; voltage having stronger effect than current. The response dose rate has linear relation to voltage and has both linear and quadratic relation to current. The interaction effect was also statistically significant. The estimated dose rate depending on two factors can be given by following equation:

$$Y = 5.138V + 74.350A - 635A^2 + 0.913A.V - 1076.565 \text{ rads/10mins} \quad \text{.....(1)}$$

Where V and A are voltage and current of X-ray tube.

Average dose rates measured with three replications and calculated dose rates calculated from equation (1) are shown in table 1.

Table 1. Measured and calculated dose rates depending on voltage and current of X-ray tube.

Voltage (kV)	Current (mA)	Dose rate measured* (rads/10min)	Dose rate calculated (rads/10min)
	10	978	958
	12	1092	1096
130	14	1206	1188
	16	1263	1236
	10	1244	1243
	12	1359	1418
150	14	1558	1547
	16	1596	1631
	10	1558	1528
	12	1672	1739
170	14	1957	1905
	16	2004	2026
	10	1805	1814
	12	2071	2061
190	14	2308	2264
	16	2413	2421

Average values from three replications.

4. Influence of exposure geometry

Figure 2 shows that dose rate decreased with increase in distance when Fricke dosimeters were exposed at the same dose but different distances in a vertical position. The estimated dose rate in range of 5-35cm can be computed by Eq. 2 with correlation coefficient value of 0. 987. For the distances more than 35cm, the influence of scattering caused decreasing correlation coefficient value.

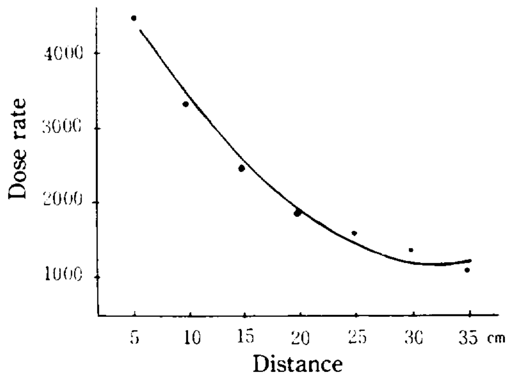

Fig. 2. Effect of distance on dose rate for 10min.

$$Y = 5445.72 - 252.84D + 3.74D^2 \text{rads/10mins} \cdots (2)$$

where D is a distance in centimetre.

5. Influence of voltage and distance

For the purpose of testing the effect of the different voltages and distances. The 4×4 factorial experiment was carry out by using Fricke dosimeter. Statistical analysis insisted that voltage was the major factor of X-ray intensity. The influence of voltage and distance to dose rate is expressed by :

$$Y = 12176.89 - 123.84V + 0.334V^2 + 317.28D - 1.42V \times D \text{ rads/10mins} \cdots\cdots (3)$$

Average dose rates measured with three replications and calculated dose rates calculated from equation (2) are shown in table 2.

Table 2. Measured and calculated dose rates depending on voltage of X-ray tube and exposure geometry

Voltage (kV)	Distance (cm)	Dose rate measured * (rads/10min)	Dose rate calculated (rads/10min)
130	5	2394	2386
	10	3068	3049
	15	3743	3712
	20	4408	4376
150	5	1586	1637
	10	2118	2159
	15	2650	2680
	20	3163	3201
170	5	1282	1156
	10	1539	1535
	15	1957	1915
	20	2346	2294
190	5	921	942
	10	1130	1179
	15	1453	1417
	20	1662	1654

Average values from three replications.

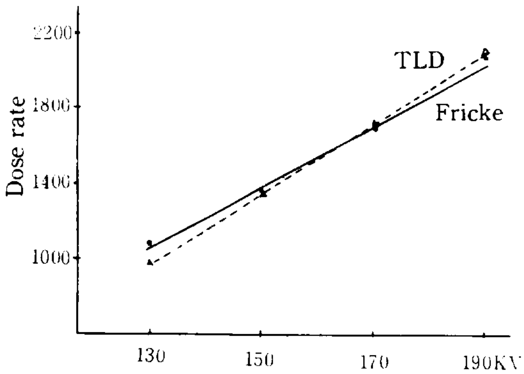

Fig. 3. The response of Fricke dosimeter and TLD to voltage of X-ray tube. The irradiation time was 10 min.

6. The response of Fricke dosimeter and TLD to X-ray irradiation

Fricke and LiF dosimeters were irradiated in four different voltages while the other factors were held constant. Figure 3 illustrates both Fricke and LiF dosimeters linearly respond to voltage with the same regression coefficient at 5% significant level.

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