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ABSTRACT

The relative biological effectiveness (RBE) for low-LET radiation is known to depend on such factors as LET and dose rate. Microdosimetric calculations indicate that the biological target size could also be an important parameter, and calculations predict that the RBE for effects produced by hits in target sizes below about 100 nm should be unity for all low LET radiation. We have measured the RBE for gene conversion in yeast (a small target) for five different low LET photon sources, and the results were consistent with an RBE of unity, which agrees with microdosimetric predictions.

INTRODUCTION

Radiation quality is normally estimated using the linear energy transfer (LET); radiation with LETs less than 10 kVp μm^{-1} are called low-LET and the quality factor versus LET relationship predicts a range in radiation quality of about 0.5 to 2.(1) Similar values are predicted when the quantity lineal energy is used to define radiation quality.(2) However, linear energy theory predicts that radiation quality is dependent on the size of the biological target, and the ratio of tritium beta rays (LET ≈ 6.5 kVp μm^{-1}) to ^{60}Co gamma rays (LET < 1 kVp μm^{-1}) has a maximum of about 3 for a target size of 1 to 3 μm, and decreases to unity for smaller and larger target sizes.(3)

Gene conversion in irradiated yeast is generally thought to result from DNA damage in the immedite vicinity of the mutant gene, and hence represented a small target that can be used to test this microdosimetric prediction. The repair of this damage can result in the mutant gene being converted to the "wild" type which will form colonies when plated onto growth medium. These colonies can be counted, and hence the gene conversion yield as a function of dose estimated.(4)

EXPERIMENTAL

Gene-conversion yields in two mutant varieties of the yeast, *Saccharomyces cerevisaie*, were measured (see Fig. 1) following irradiation with five different sources of low-LET radiations that essentially span the range of LET for low-LET

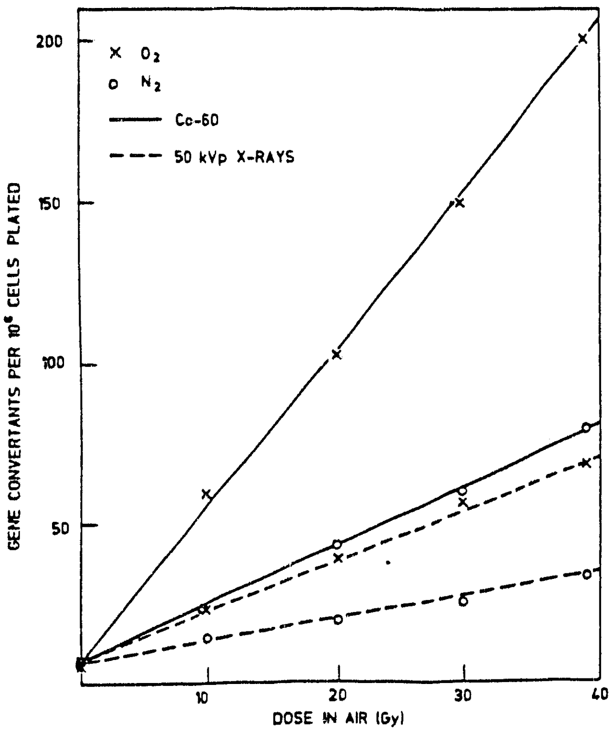

Fig. 1. Typical results obtained for gene conversion yield as a function of dose. The dose to cells from the 50 kVp x-rays are considerably less than the dose in air (see Table 2).

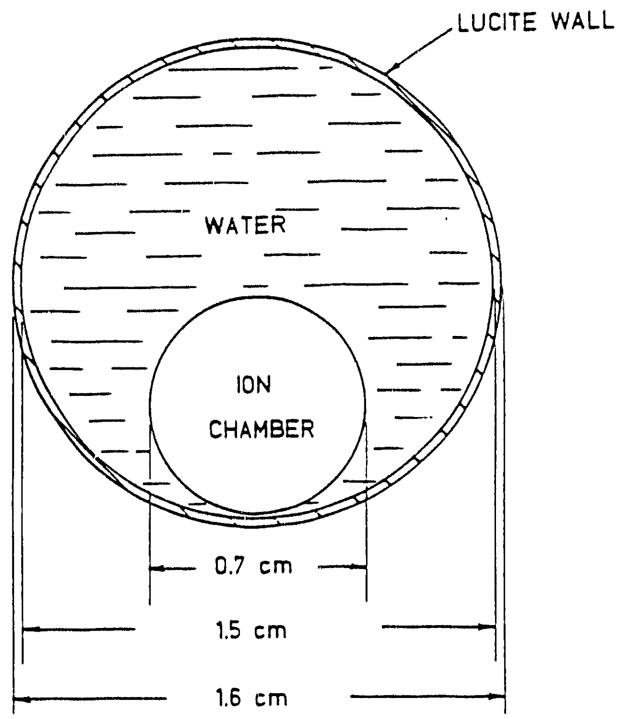

Fig. 2. Experimental arrangement doses to cells. The ion chamber was normally at an equal dose position to the lucite test tube containing yeast cells suspension.

radiations normally encountered in the workplace. These radiations are 50 to 150 kVp x-rays from a thin window (2.5-mm Be) x-ray tube, 150 and 300 kVp x-rays from a thick window (0.4-mm Cu) x-ray tube, and ^{60}Co gamma rays. The x-rays emitted from the thin window tube have a much higher LET (50 kVp thin window ≈ 7.5 kVp/μm, 150 kVp thin window ≈ 2.5 kVp/μm) than those from the thick window tube (150 thick window = 1.5 kVp/μm, 300 thick window = 1.0 kVp/μm). The gamma rays from ^{60}Co have an even lower LET (~0.26 kVp/μm). The dose rates used in all experiments were about 100 rad/min, which is well below that which produces dose rate effects, based on previous experience with this system by the authors.(4)

Cells were suspended in growth medium in lucite test tubes and maintained at 0°C (ice bath) during irradiation. Air (O_2) or N_2 gas bubbled through the medium to give yields under oxic and anoxic conditions.

Typical results are shown in Fig. 1. The slopes (b_i) of straight line fits to the data were estimated and their ratios and uncertainties obtained from the formula

$$R = \frac{b_x}{b_\gamma} \pm \left[\frac{\Delta b_x^2}{b_\gamma^2} + \frac{b_x^2\, \Delta b_\gamma^2}{b_\gamma^2} \right]^{1/2}$$

and are given in Table 1. Δb_i are the uncertainties returned by the fitting routine.

The much lower yield for the 50 kVp irradiations results from the average dose to cells being much smaller than that in air for these lower energy x-rays because of absorption in the lucite tube and in the suspension. The absorption for all irradiations was estimated using two methods. First, theoretical energy spectra of the x rays was used to calculate the average dose to cells using known absorption cross sections. These values were checked by inserting the ion-chamber into a water filled tube (Fig. 2) and the average dose measured. The correction for absorption was applied to the ratio of slopes to obtain the RBEs in Table 2.

DISCUSSION AND CONCLUSION

The estimated RBE (Table 2) for the TRP (N_2) mutant are all less than 1, and those for the HIS(O_2) are all greater than 1, indicating that there may be some unexplained bias in the results. However, the overall results are consistent with an RBE close to unity and are experimental support for the prediction of the microdosimetric theory that the RBE for low LET irradiations of small biological tangets is approximately one.

REFERENCES

1. International Commission on Radiological Protection. Recommendations of the International Commission on Radiological Protection. Publication 26, Pergamon Press, New York (1977).

2. The Quality Factor in Radiation Protection. International Commission on Radiological Protection and International Commission on Radiation Units and Measurements. Publication 40, ICRU, Bethesda, Maryland (1986).

3. J. Booz and H.G. Paretzke. Microdosimetric considerations for the quality factor of tritium. Radiation Protection. Commission of the European Communities Report. EUR8712EN (1984).

4. D.K. Myers and J.R. Johnson. Toxicity and Dosimetry of Tritium: A Review. ACRP-10, INFO-0377 (E), Advisory Committee of the Atomic Energy Control Baord of Canada, Ottawa, Canada.

TABLE 1. Ratio of the slopes obtained from the straight line fitting routine to the gene conversion data (See Fig. 1). The values in parenthesis are twice the standard error calculated from the error estimate in the slope as returned by the fitting routine. (1) are with thick window x-ray set, and (2) are with thin window.

Experiment	Ratio of Slopes			
	TRP		HIS	
	O_2	N_2	O_2	N_2
300 (1)	1.02(0.03)	0.84(0.05)	0.99(0.07)	9.85(0.05)
150 (1)	1.00(0.03)	0.92(0.03)	0.97(0.07)	0.94(0.05)
150 (2)	0.42(0.03)	0.41(0.01)	0.51(0.03)	0.48(0.02)
50 (2)	0.34(0.03)	0.31(0.01)	0.41(0.04)	0.34(0.03)

TABLE 2. RBEs for gene conversion in yeast induced by the indicated x-rays, as compared to ^{60}Co gamma rays. The values in parenthesis are twice the standard error, including the estimated contribution from uncertainty in dose estimates. (1) are with thick window x-ray set, and (2) are with thin window.

X-ray Source	Corrected RBE			
	TRP		HIS	
	O_2	N_2	O_2	N_2
300 (1)	1.07(0.05)	0.88(0.06)	1.04(0.08)	1.00(0.06)
150 (1)	1.05(0.05)	0.97(0.05)	1.02(0.08)	0.99(0.06)
150 (2)	0.93(0.08)	0.91(0.06)	1.13(0.08)	1.07(0.07)
50 (2)	1.02(0.14)	0.93(0.11)	1.23(0.17)	1.02(0.14)

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