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CALIBRATION OF ^{90}Sr + ^{90}Y PLAQUES

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ABSTRACT

Calibration dose-rate measurements have been made above two 34 cm diameter plane-disk sources containing approximately 75 mCi and 750 mCi of ^{90}Sr + ^{90}Y , respectively. The contact dose rate in the center of the 75 mCi source was 656 rads/hr and the measured dose rate at contact in the center of the 750 mCi source was 4950 rads/hr. The data presented in this report are intended to be useful in planning the design of irradiation experiments with insects, in choosing desirable dose rates, and in estimating total doses.

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INTRODUCTION

Three plane disk $^{90}\text{Sr} + ^{90}\text{Y}$ sources have been constructed by the Radiation Ecology Section for irradiating insects with beta rays.² Each source is 34 cm in diameter and contains approximately 75 mCi, 750 mCi, or 7500 mCi of $^{90}\text{Sr} + ^{90}\text{Y}$ covered by 5-mil Al foil. Preliminary calibration of the sources was done by Menhinick² with X-ray film, a cutie pie ion chamber, and a vibrating reed electrometer which resulted in approximate estimates of the radiation dose rates above each source. More accurate estimation of dose was deemed necessary to obtain maximum usefulness of the sources for relating dose to biological effects in insects. This report pertains to experiments with only the low- and intermediate-level sources.

The objectives of this study were: (1) estimation of the maximum energy of the beta radiation, (2) delineation of the dose-rate distribution above the sources, (3) calibration of a glass rod dosimetry system which could be used during the irradiation of insects, and (4) recommendations for construction of containers that would result in uniform dose rates to irradiated insects.

MATERIALS AND METHODS

Feather Analysis

Feather's method of range determination for beta rays, as described by Bleuler and Goldsmith,³ was utilized to estimate the maximum beta-ray energy to which insects would be exposed. The Feather analyzer utilized

²Menhinick, E. F. Health Phys. 12, 973 (1966).

³Bleuler, E. and G. J. Goldsmith, Experimental Nucleonics, Rinehart Publishing Co., N. Y. (1952).

a ^{32}P point source and a Nuclear Chicago Model 2800-A scaler fitted with an end window GM tube. A lead collimator with a pin hole (0.079 cm diameter) was centered below the GM tube window. Detector and collimator were suspended 1.6 cm over a plane source so that only those beta particles from an approximate point source were detected. Aluminum absorbers were placed between the pin hole and the source to obtain data for the absorption curve. The absorption curve was analyzed with the Feather analyzer from the ^{32}P source to determine maximum range of beta rays emitted from the encapsulated $^{90}\text{Sr} + ^{90}\text{Y}$ source.

Dosimetry

An extrapolation ionization chamber⁴ was used as a reference dosimeter for beta dose rates above the low-level source. This precision instrument is a plane-parallel ionization chamber of variable gap between collecting electrode and high-voltage electrode. The peak-to-noise level of the assembled unit was approximately $2 \times 10^{-16}\text{A}$, and the leakage current was about $5 \times 10^{-17}\text{A}$. The extrapolation chamber was suspended above the center of the $^{90}\text{Sr} + ^{90}\text{Y}$ disk, and dose-rate measurements were made with an 11 mm diameter collecting electrode positioned at contact, 1.3 cm, 3.8 cm, and 6.4 cm above the source. Dose rate was extrapolated to zero chamber volume.

Silver metaphosphate glass rods (Toshiba Low Z FD-R1-1A, 1 x 6 mm) were used to delineate the dose rate distribution above the sources, and to estimate the magnitude of the Bremsstrahlung radiation. Before usage, each rod was cleaned in a detergent bath agitated with an ultrasonic

⁴Loevinger, R. and N. G. Trott, Intern. J. Appl. Rad. and Isotopes 17, 103 (1966).

generator. The fluorescent outputs of exposed rods were determined with a modified Bausch and Lomb Microdosimeter reader which was calibrated with rods exposed to known doses from ^{60}Co at the National Bureau of Standards. Since the Bremsstrahlung radiation was found to be always less than 0.5% of the dose rate, the glass rods were calibrated against the extrapolation ionization chamber for response to beta radiation. The ratio of the beta to gamma response for Toshiba rods was 0.785.

A circular lucite template (40.6 cm diameter x 0.95 cm thick) of the source was scribed with radial lines at 45° and cross-hatched at consecutive 2 cm distances from the center. The cross-hatch marks were used to position rods above the source angularly and radially. Rods were affixed with double-face masking tape to the side of the template facing the source. The lucite template was placed at variable heights above the source by means of plywood spacers. Five glass rods were suspended over the center of the low-level source at heights of 0.24 cm, 2.14 cm, 3.41 cm, and 5.64 cm; and over the intermediate-level source at heights of 1.27 cm, 3.18 cm, 4.45 cm, and 5.72 cm. Rods were held horizontally, parallel to the plane of the source, and uniformly spaced within an effective area of 11 mm in diameter. Bremsstrahlung dose was measured with glass rods placed above the lucite plate. The 0.95 cm thickness of lucite was determined by the Feather analysis to be sufficient to stop all beta rays from the encapsulated source.

RESULTS

Maximum Beta-Ray Energy

The maximum range (R) of beta-ray energies emitted from the low-level source was 1.06 g/cm^2 using Feather's analysis as previously described.

From Feather's rule for the range-energy relationship, $R = 0.542 E_{\max} - 0.133$, the maximum energy ($E_{\max}$) was calculated to be 2.20 Mev. The maximum beta particle range was 1.10 gm/cm^2 when corrections for the 35 mg/cm^2 aluminum encapsulating cover were included giving a maximum beta energy of 2.27 Mev.

Dosimetry

Low-Level Source

The contact dose rate measured with the extrapolation chamber at the center of the low-level source was 656 rads/hr, and decreased exponentially with increasing height above the source. The response of glass rods showed a similar exponential decrease with height. Dose rate (rads/hr) as a function of height above the source is plotted in Fig. 1 for the extrapolation chamber and the glass rods. The glass rods were calibrated with the ionization extrapolation chamber by using the factor 3.24 to normalize and convert all fluorometer readings to rads.

Dose rate distribution over the surface of the source was measured with glass rods at 2.22 cm (Fig. 2a) and at 4.13 cm (Fig. 3a). The corresponding isodose lines constructed from dosimeter readings are shown in Figs. 2b and 3b. The isodose graphs are only approximations of the dose-rate distributions, because much closer spacing of dosimeters would be required to eliminate the arbitrary extensions of the contours between dosimeter readings. Dose rates at successive radial distances were averaged and plotted on linear graph paper (Fig. 4). This figure shows that from the center to 4 cm, the average dose rate at 2.22 cm height is approximately 550 rads/hr. At 4.13 cm height (Fig. 5) the mean dose rate out to 4 cm radially is about 430 rads/hr (less than 1 rad/hr was attributable to Bremsstrahlung radiation).

Fig. 1. Dose Rate vs. Height above Center of Low-Level Source (75 mCi $^{90}\text{Sr} + ^{90}\text{Y}$).

Fig. 2. Dose Rates (rads/hr) at 2.22 cm above Low-Level Source (75 mCi $^{90}\text{Sr} + ^{90}\text{Y}$). a. Angular and Radial Distribution. b. Dose-rate Contours (Contour interval is 25 rads/hr).

Fig. 3. Dose Rates (rads/hr) at 4.13 cm above Low-Level Source (75 mCi ^{90}Sr + ^{90}Y). a. Angular and Radial Distribution. b. Dose-rate Contours (Contour interval is 20 rads/hr).

Fig. 4. Average Dose Rate (± 1 Std. Dev.) vs. Radial Distance from Center at 2.22 cm above Low-Level Source (75 mCi ^{90}Sr + ^{90}Y).

Fig. 5. Average Dose Rate (± 1 Std. Dev.) vs. Radial Distance from Center at 4.13 cm above Low-Level Source (75 mCi $^{90}\text{Sr} + ^{90}\text{Y}$).

Intermediate-Level Source

Dose rates from the intermediate-level source were measured with glass rods only. Dose rate again varied exponentially with distance above the center of the source (Fig. 6). When the straight-line plot was extrapolated to zero (see Fig. 6), the contact dose rate at the center of the disk was approximately 4950 rads/hr. Dose rate distribution over the source was measured at heights of 1.91 cm and 4.45 cm. These data were handled in the same manner as with the low-level source and are presented in Figs. 7, 8, 9 and 10.

The Bremsstrahlung dose rate was approximately 2 rads/hr at a height of 4.45 cm.

DISCUSSION

Menhinick⁵ stated that activity was distributed uniformly within $\pm 5\%$ over the surface of the source plaques. Mean readings of glass rods at equal radii from the center of the source gave standard deviations ranging from 4 to 10%. The glass rods irradiated by the National Bureau of Standards gave standard deviations of about 3% for replicate readings. Therefore, additional variation in dose-rate measurements at equal radii from source centers are presumably due to minor fluctuations in activity distribution. This is illustrated by the irregular shape of the isodose curves. All the curves relating average dose rate and radial distance, irrespective of height, are relatively flat out to 4 cm from the center of the source. This center area of each source (50 cm^2) appears to be the most useful part of the surface for irradiating insects, if the specimens are positioned within the vertical heights shown in the figures.

⁵Menhinick, op. cit., 973.

Fig. 6. Average Dose Rate (± 1 Std. Dev.) vs. Height above Center of Intermediate-Level Source (750 mCi ^{90}Sr + ^{90}Y).

Fig. 7. Dose Rates (rads/hr) at 1.91 cm above Intermediate-Level Source (750 mCi $^{90}\text{Sr} + ^{90}\text{Y}$). a. Angular and Radial Distribution. b. Dose-rate Contours (Contour interval is 200 rads/hr).

Fig. 8. Dose Rates (rads/hr) at 4.45 cm above Intermediate-Level Source (750 mCi ^{90}Sr + ^{90}Y). a. Angular and Radial Distribution. b. Dose-Rate Contours (Contour interval is 200 rads/hr).

Fig. 9: Average Dose Rate (± 1 Std. Dev.) vs. Radial Distance from Center at 1.91 cm above Intermediate-Level Source (750 mCi ^{90}Sr + ^{90}Y).

Fig. 10. Average Dose Rate (± 1 Std. Dev.) vs. Radial Distance from Center at 4.45 cm above Intermediate-Level Source (750 mCi ^{90}Sr + ^{90}Y).

RECOMMENDATIONS

Insects should be exposed in a round plastic container, not exceeding 8 cm in diameter, and constructed with a mylar bottom. The container should be centered over the source at a height which will deliver the desired dose rate (see Figs. 1 and 6). Care should be taken to minimize the depth of the containers used to expose insects because the bottom-to-top dose rate differential is thus minimized (see Table 1). Likewise, possible vertical movements of insects should be eliminated.

Table 1.
Percent Dose Difference from the Top to Bottom
of a Container of a Given Depth

Low-Level Source		Intermediate Level Source	
Container Depth (cm)	% Dose Difference from Top to Bottom	Container Depth (cm)	% Dose Difference from Top to Bottom
0.32	2.0	0.64	2.5
0.64	6.0	1.27	3.5
1.27	10	1.91	6.0
1.91	20	2.5	10

The gain on the microdosimeter reader should be adjusted so that the response corresponds to 2.54 rads/fluorometer unit for rods irradiated with ^{60}Co by the National Bureau of Standards. This sensitivity will correspond to 3.24 rads from beta rays/fluorometer unit, or a beta to gamma response ratio of 0.785.

The high-level source (presently located in a vault) should be housed in a shielded container so that it may be calibrated with the glass rod dosimetry system described in this report.

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