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ESTIMATION OF BETA RADIATION DOSE TO THE SKIN BY MEANS OF FIELD INSTRUMENT MEASUREMENTS

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ABSTRACT

There are two basic problems in beta dosimetry monitoring for dose rates to the skin from small-area sources: one is that of determining the dose rate when the source is in contact with the skin; the other is when the beta-emitter is a contaminant "on" or "in" the skin. In neither case do the readings which may be obtained with field-type survey instruments represent directly the dose rate to the skin. In fact, the skin dose rate may be as much as 1000 times the observed instrument reading, even though the instrument is very near the source when the reading is obtained.

The response of field-type radiation survey instruments to beta radiation from small-area sources has been determined. Observational readings were made with typical instruments at various distances from beta sources which were prepared for the purpose. The dose rates to the skin from such sources, at various source-to-skin distances, were derived from measurements and calculations.

From the data obtained in these experiments and from calculations it appears that, by proper interpretation of the measurements, field-type instruments may be used to obtain an adequate estimate of skin dose rates from small-area beta sources. Proposed methods are outlined for estimating (1) the dose rate from a source in contact with the skin and (2) the dose rate from contamination on the skin.

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INTRODUCTION

There are many cases for which there is a need to estimate the skin dose from small-area sources of beta radiation without recourse to specialized techniques and instruments. Most of the cases involve skin contamination or small sources handled with the fingers.

Several methods have been reported[1,2,3] for calculating the dose if the quantity and distribution of the source material are known, but in the cases considered here such information is not known.

Although rather sophisticated instruments and techniques[4,5,6] may be used when warranted, one would like to be able to evaluate the hazard, at the time and location of the work, with routine monitoring instruments. However, the readings obtained with those instruments are less than the absorbed dose rate to the skin, which may be orders of magnitude greater than the observed dose rate reading.

PROCEDURE

Several kinds of portable radiation monitoring instruments were used to find their response to beta sources. The beta sources were prepared by depositing a liquid solution which contained the radioactive material onto a plastic disc so that the source material was within a circular area of one square centimeter. The mass absorber thickness of the sources was less than 0.1 mg/cm^2. Each source contained only one radioisotope, except for negligible impurities. The radioisotopes were selected to cover a wide range of beta energies, to have only one beta energy per source (except ^{111}Ag) and to emit no gammas (except ^{60}Co). The quantities of radioactivity in the sources were selected to obtain readings of significant magnitude with the dose rate instruments and to avoid excessive counting rates with the Geiger counter instruments.

Dose rates to skin at a depth of 7 mg/cm^2 below the surface averaged over a circular area of 1 cm^2 were derived from measurements and calculations for each of the sources at several source-to-skin distances. The area of the source and the area of skin considered (1 cm^2, each) were chosen with regard for actual cases and with the assumption that high intensities in very small areas may be averaged over an area of at least 1 cm^2.[7]

RESULTS

The isotopes which were used and the absorbed dose rates (averaged over a circular area of 1 cm^2 at a depth of 7 mg/cm^2) in skin at various distances from sources of one microcurie are shown in Table I. The "in" skin dose rates are based on the source material having penetrated to a depth of 3.5 mg/cm^2 beneath the surface of the skin. The "on" skin dose rates are based on the source material being on the surface of the skin.

Readings which were obtained with some of the instruments are shown in Tables II and III. The distances noted are those from the surface of the source to the surface of the detector. Although not shown here, the readings of the Juno and the V-440 (with 2 mg/cm^2 absorber added to the standard windows) were about one-tenth of the absorbed dose rate in the skin at that distance.

The values for dose rates to the skin (Table I) are significantly less than the published values for large area sources and somewhat less than the central axis dose rate from small area sources.[1,2,3] Dosimetric measurements were made with a beta scintillator, which was referenced to an extrapolation chamber, and photographic films.[8]

As was expected, beta radiation of low energy (less than 0.2 MeV, E_o) was found to be relatively undetectable with counters such as the 1B85 (30 mg/cm^2, Al) and the 106C (30 mg/cm^2, S.S.). The standard, thin windows of the Juno and the V-440 transmitted relatively more of the lower energy betas than would the skin. A window thickness of about 4 mg/cm^2 was found to be the optimum for skin dosimetry use so that an approximate constant of proportionality between skin dose rate and instrument reading may be applied (Table II).

CONCLUSION

The Juno and the V-440 survey instruments may be used in estimating the average, absorbed dose rate in the skin from beta sources which are of small area. If the area of the source is not greater than 1 cm^2, and if the window thickness is about 4 mg/cm^2, a multiplying factor may be applied to the observed dose rate to obtain the average dose rate in the skin. The multiplying factor is a function of source-to-detector and source-to-skin distance.

It may be inferred that a mask or a factor which includes consideration for the area of the source may be applied to estimate the average dose rate from sources with areas on the order of a few cm^2. The large or "infinite" area source presents no problem if window thickness vs. skin thickness is considered.

A thin (approximately 2 mg/cm^2) window, GM Counter which has a sensitive area slightly greater than that of the source may be used, by application of a multiplying factor, to estimate the dose rate from small area, low activity, beta sources on the skin (Table III). Each such counter should be standardized individually, because there are large differences among the beta radiation detection efficiencies of end window counters, even between counters of the same model and lot of a given manufacturer.

The foregoing methods may be used for approximating skin doses, without need to know the beta energies, if the source material is in contact with the surface skin. It is important to note that the observed dose rate will be less and the skin dose rate will be greater if the lower energy beta emitters have penetrated into the skin, as may be the case after decontamination efforts have been applied.[3,9]

TABLE I

One Cm^2 Sources and Average Dose Rates to One Cm^2 of Skin

Source (1 μc each)	Betas	mrad/hr "In" Skin(a)	mrad/hr "On" Skin(b)	mrad/hr @ 1 cm	mrad/hr @ 10 cm
^{32}P	1.71 MeV, 100%	2000	2000	200	22
^{89}Sr	1.46 MeV, 100%	2100	2000	200	22
^{111}Ag	1.04 MeV, 91% 0.69 MeV, 8%	2000	1900	190	20
^{36}Cl	0.7 MeV, 98.3%	2000	1900	190	19
^{185}W	0.43 MeV, 100%	2100	1700	160	14
^{60}Co	0.31 MeV, 100%	2200	1500	135	12
^{147}Pm	0.22 MeV, 100%	2100	1100	90	3.3

(a)Source at a depth of 3.5 mg/cm^2 in skin.

(b)Source on surface of skin.

TABLE II

Readings with Ion Chamber Instruments
At 1 Cm from Sources on Skin vs. Skin Dose Rates

1 μc Source	Skin mrad/hr	Juno mrad/hr	V-440 mrad/hr		$\frac{\text{V-440}^{(b)}\ \text{mrad/hr}}{\text{Skin dose rate}} \times 100$
			(a)	(b)	
^{32}P	2000	26	28	28	1.4
^{89}Sr	2000	27	29	29	1.4
^{111}Ag	1900	25	26	26	1.4
^{36}Cl	1900	25	27	25	1.4
^{185}W	1700	24	26	23	1.3
^{60}Co	1500	24	24	19	1.3
^{147}Pm	1100	21	21	15	1.3

(a) With standard window.

(b) With standard window plus 2 mg/cm^2.

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TABLE III

Counting Rates of GMSM Instruments at 1 Cm from Small-Area, One-Tenth μc Sources, on Skin vs. Dose Rate to Skin

Source	Skin mrad/hr	1B85 cts/min	106C cts/min	E.W. (1 in) cts/min
^{32}P	200	6000	5100	22,000
^{89}Sr	200	5500	4000	22,500
^{111}Ag	190	3700	2500	20,500
^{36}Cl	190	3800	1500	18,000
^{185}W	170	1100	300	15,500
^{60}Co	150	500*	350*	14,000
^{147}Pm	110	15	< 10	11,500

* γ emitter, also.

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