AGE FACTORS FOR DOSE RATES FROM AN INFINITE CLOUD
OF A PHOTON EMITTER*

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Abstract

Estimates of dose to many of the various organs of the body have been given for an adult immersed in an infinite cloud of a photon emitter (Health Phys. 26, 287, 1974). Similar results are now available for phantoms representing individuals of ages 0 (newborn), 1, 5, 10, and 15 years of age. In this paper we examine the ratio of the dose rates received per microcurie-hour of exposure of the younger individuals to that for the adult. The results can be expressed as a set of curves, one for each target organ, and for the different ages. In general, the ratios are higher for the younger individuals and for the newborn are frequently higher by a factor of 10 or more. There are a number of departures from this simple generalization which can be interpreted in terms of depth of the organ below the surface of the body, photon energy, etc. These curves are convenient for calculation of the doses received by various segments of the population or for estimation of the average dose received by a population from an infinite cloud source. Examples are given for $^{85}$Kr and $^{133}$Xe.

Immersion in a cloud of radioactive gas is an important pathway of exposure for the population around nuclear reactors or fuel processing plants. However, the estimates of the dose rate due to a cloud source are based usually on the adult and, in many cases, are only for a dosimeter exposed to the cloud, that is, a dosimeter representing a small mass of tissue. Recently, the authors discussed a more realistic model for dose rate to body organs of an adult (Poston and Snyder, 1974) which gave estimates of dose rate from 12 monoenergetic cloud sources of photons for 21 body organs as well as an estimate of the whole body dose. In this paper, the dose rates to children, or persons of smaller body size, are considered to see whether the dose estimates for the cloud are reasonably valid for the population as a whole. It should be emphasized that the data given below, and also those data published previously for the adult, apply only for dose rate received from the external cloud and does not apply to the absorption of the gas within the tissues of the body.

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The phantoms used to represent the children are those which have been studied for internal sources for a number of years at the Oak Ridge National Laboratory (W. S. Snyder, et al., 1971). They are obtained by shrinking the head, the trunk, and the leg section of the adult phantom by three independent linear transformations. This permits the size of the head, trunk, and legs to be varied independently. The dimensions chosen for the phantoms are based on a study of data presented in the Report on a Reference Man (ICRP, 1974) and are chosen to represent possible median values of the distribution of dimensions for the specified age groups, i.e., the newborn child, and children of ages 1, 5, 10, and 15 years. These dimensions together with the adult are listed in Table 1 and an outline of the phantoms is shown in scale in Figure 1.

When the transformations are applied to the adult phantom a phantom having the dimensions of the specified child phantom is obtained for the head, the trunk, and the legs. However, other internal organs may be somewhat distorted. No attempt has been made to redesign the child phantoms to give them the approximate size and shapes of organs as is desirable, and from this point of view the results obtained here are preliminary. Experience thus far has indicated that the dose is reasonably insensitive to small changes in mass and shape when the source is outside the target organ (Snyder, 1970) as it is in this case since it is exterior to the body.

Each of the twelve monoenergetic sources have been processed by the computer code of Dillman (Dillman, 1974) to produce the energy spectrum of the scattered photons incident on the surface of the phantom. In fact, the identical spectra were used for each calculation as were used for the adult phantom although the sample selection was random, being 60,000 photons in each case. These photons were allowed to impinge on the exterior surface of the phantoms and doses were recorded as usual in the tissues where the interactions take place.

Results were adjusted for each phantom after considering differences in the surface area of each smaller phantom and the photon flux density incident on the surface of the phantoms. Figures 2, 3, and 4 show the results for three parts of the body chosen to represent typical results of the calculations. The ratio of absorbed dose (in rads/day) to each phantom to that of the adult is plotted as a function of age (body size) for several monoenergetic photon clouds. Figure 2 shows the dose ratios for the skin for energies of 0.01, 0.1, and 1 MeV. The skin was chosen since it represents essentially the surface dose to an individual exposed to the cloud. Many dose estimates given today give only this surface dose. For the lowest energy shown, the dose ratio increases as the phantom age decreases; however, for more energetic photons little change in the ratio is shown. For photons of about 0.01 MeV the mean free path in tissue is about 0.2 cm, thus most of the energy is deposited in the skin. For photons of higher energy the mean free path is much greater (~6.5 cm for 0.1 MeV photons) and the dose to the skin remains essentially constant.

The dose ratios for the red bone marrow are shown in Figure 3 for the same three energies. The red marrow can be considered as a distributed organ since all parts of the skeleton except the lower arms and the lower legs contain red bone marrow. Here, the dose ratios for low energy photons increase dramatically as the age of the phantom decreases (about a factor of 7 for the newborn). As the photon energy increases, there is a leveling of the dose ratio curve. Note, however, that the newborn is still about 20% higher than the adult at 1.0 MeV.

Figure 4 shows the dose ratio values for the liver, a rather large organ (1,809 gms in the adult) occupying a significant volume on the right side of the phantom. Here again the results are quite similar to those for the red bone marrow. That is, a large increase in the dose ratio for the low energy photon cloud with little change in the dose ratio as the photon energy is increased.
Table II illustrates the manner in which these dose ratios might be used. From our previous data on the adult (Poston and Snyder, 1974) the absorbed dose to the skin, liver, red bone marrow, and the total body due to immersion in a cloud of $^{85}$Kr or $^{133}$Xe have been estimated by interpolation. In addition, the dose ratios for these two radionuclides for the younger phantoms are given. Thus, by simple multiplication, the dose to these organs can be estimated for the five smaller phantoms. Due to space limitations a comprehensive set of dose ratios cannot be published here. However, these data can serve to illustrate their usefulness in the estimation of dose to population groups.

References


L. T. Dillman, "Absorbed Gamma Dose Rate for Immersion in a Semi-Infinite Radioactive Cloud," Health Physics, accepted for publication.

<table>
<thead>
<tr>
<th>Radiation</th>
<th>Organ</th>
<th>Absorbed Dose to 7% Inc.</th>
<th>Tissue</th>
<th>Bone</th>
<th>Brain</th>
<th>1 year</th>
<th>5 years</th>
<th>10 years</th>
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<td>Kr-85</td>
<td>Skin</td>
<td>9.23 x 10^{-3}</td>
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<td>Lung</td>
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<td>1.058</td>
<td>1.186</td>
<td>1.223</td>
<td>1.215</td>
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<td>Bone</td>
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<td>Total Body</td>
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<td>Xe-133</td>
<td>Skin</td>
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<td>Brain</td>
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Relative Size of Phantoms for 0, 1, 5, 10, 15, and 20 Years.
ratio of dose to child to dose to adult

monoenergetic photon cloud
red bone marrow

Dc/Da

0.01 MeV
0.1 MeV
1.0 MeV
10 MeV

(NEWBORN) 0 5 10 15 ADULT

AGE (YEARS)