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Fluence to Effective Dose and Effective Dose Equivalent Conversion Coefficients for Photons from 50 KeV to 10 GeV

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Abstract

Effective dose equivalent and effective dose per unit photon fluence have been calculated by the FLUKA code for various geometrical conditions of irradiation of an anthropomorphic phantom placed in a vacuum. Calculations have been performed for monoenergetic photons of energy ranging from 50 keV to 10 GeV. The agreement with the results of other authors, when existing, is generally very satisfactory.

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INTRODUCTION

As well known, the radiation protection system based on dose equivalent limits for single organs and for the whole body was supplemented by the introduction of the quantity effective dose equivalent in ICRP Publication 26[1]. This quantity has been more recently replaced by the effective dose in ICRP Publication 60[2]. However, since the dose limits are still expressed in terms of effective dose equivalent in many countries, i.e. the countries of the European Community, Italy included, both quantities have been considered in this paper.

Effective dose equivalent and effective dose are both not measurable quantities. Their values can be determined from those of physical quantities (i.e. particle fluence) only by calculation. To this aim, conversion coefficients derived in standard conditions of exposure are used in practice. As concerns photon radiation, sets of conversion coefficients in terms of effective dose equivalent have been recommended by the International Bodies (ICRP[3] and ICRU[4]) only up to 10 MeV. In contrast, official conversion coefficients in terms of effective dose are still completely lacking. However, a report on this matter is announced to be published jointly by ICRP and ICRU[5]. Recently the results of some calculations of effective dose in the photon energy range 1 MeV-10 GeV appeared in literature[6], restricted to anterior-posterior and posterior-anterior irradiations.

In the present paper the results of calculations of conversion coefficients from photon fluence to respectively effective dose equivalent and effective dose are presented for several geometries of irradiation of an anthropomorphic phantom, in the energy range from 50 keV to 10 GeV.

It should be noted that the fluence to dose conversion coefficients at high energies are the basic data for various purposes, like shielding calculations for high energy particle accelerators, dose evaluations around targets hit by high energy particle beams, gas bremsstrahlung estimates, space activities, etc. Their utility is even more evident if one considers that ICRU and ICRP have not recommended any operational quantity for photon energy above 10 MeV.

Though the major interest of this study is for high energy photons, also the energy range below 10 MeV has been investigated for purposes of comparison with the existing data and with the recommended values of the fluence to ambient dose equivalent conversion coefficients.

Calculations have been carried out by the most recent version of the FLUKA Monte Carlo code(7), which simulates the development of showers initiated by high energy particles having an energy up to several tens of TeV. Details about the ability of the FLUKA code to simulate electron-photon transport are discussed elsewhere(8,9,10). The treatment of the electromagnetic cascades in the code version used has undergone fundamental changes with respect to the 1987 release. Most of the original EGS4 physics has been drastically improved or completely modified. Main improvements concern the treatment of photoelectric effect, bremsstrahlung and pair production. A detailed description of the changes and their benchmarking can be found in ref. (8, 10).

METHOD OF CALCULATION

Anthropomorphic phantom

The anthropomorphic phantom used was an hermaphrodite phantom derived from ADAM, the phantom developed by GSF(11) and recently translated in terms of the FLUKA code geometry(12). The female organs were added and some other modifications relevant for the evaluation of effective dose have been included. The most important of them concerns the specific representation of bone surfaces and red bone marrow.

Internal organs have been considered to be homogenous in composition and density. Different densities and compositions have been used for the lungs, bone, red bone marrow, soft tissues and skin. The composition of these five tissues were limited to the 14 elements H, C, N, O, Na, Mg, P, S, Cl, K, Ca, Fe, Zr, Pb. The density assumed was 0.296 $g \cdot cm^{-3}$ for the lungs, 1.486 $g \cdot cm^{-3}$ for the bone, 1.028 $g \cdot cm^{-3}$ for red bone marrow, 0.987 $g \cdot cm^{-3}$ for soft tissues, 1.105 $g \cdot cm^{-3}$ for skin. The volumes of the organs were estimated using the FLUKA code itself by track-lengths estimators.

Irradiation geometries

Calculations were performed for whole-body irradiation of the anthropomorphic phantom, placed in a vacuum, with broad parallel beams and fully isotropic radiation incidence. The directions of incidence of the parallel beams were anterior-posterior (AP), posterior-anterior (PA) and right lateral (LAT). The isotropic irradiation (ISO) has been obtained by the use of an inward-directed, biased cosine source on a spherical surface.

For the Monte Carlo calculations 20 monochromatic photon energies ranging from 1 MeV to 10 GeV were considered. In addition three energies below 1 MeV have been also investigated for purposes of comparison with data already existing in literature. The cut-off energy was set equal to 10 keV for electrons and 1 keV for photons.

As results of the Monte Carlo simulations, the energy per primary photon deposited in the 68 regions representing the various organs and tissues of the human body has been determined.

The statistical uncertainties were estimated by doing calculations in several batches and computing the standard deviation of the mean. The total number of histories was large enough to keep the standard deviation of the conversion coefficients below a few %. A greater accuracy seemed to be superfluous, in consideration that differences of 5% can be expected among the results of well proved codes(12).

Effective dose and effective dose equivalent calculation

While the definition of effective dose equivalent given in ICRP Publication 26 has been adopted here, a few changes have been introduced for the effective dose with respect to the definition given in ICRP Publication 60. According to ICRP Publication 69(13) the upper large intestine has not been included among the so called remainder to avoid duplicating the colon dose. Concerning the definition of the remainder relevant to evaluate the effective dose (ICRP 60), the rules suggested in ref. (14) have been adopted. Thus the remainder dose has been evaluated from the doses to nine additional individual organs and tissues as arithmetic mean.

Furthermore the recommendations given in footnote 3 of table 2 in ICRP Publication 60 have been ignored. It should, however, be noted that this rule is of poor concern in the case of a uniform whole body irradiation. Nevertheless some guidance on this matter would be desirable.

Guidance would also be desirable about the way of evaluating the dose received by organs or tissues spread throughout the whole body and represented in the simulation by several regions, as for instance, bone, red bone marrow, muscle, etc. Two possible methods are in principle proposable, the (arithmetic or mass weighted) mean of the doses to the single constituent regions or their maximum. In the case of a uniform external photon irradiation the differences between the two methods are usually scarcely important. It would be different in the case of a not uniform irradiation. In the present calculations, the dose to a given organ or tissue has been determined as arithmetic mean of the doses received in the single constituent regions.

According to ICRP Publication 69, the higher value of doses to the ovaries and to testes is applied to the gonad weighting factor for the calculation of effective dose and effective dose equivalent.

The dose to the muscles has been assumed as the arithmetic mean of the doses received by that part of the body volume which is not attributed to any other organ or tissue of the model.

RESULTS AND DISCUSSION

The results of this study are summarised in tab. 1 and 2 respectively for the effective dose equivalent and for the effective dose. Statistical uncertainties (standard deviations) are presented following each value. The same data are also shown in fig. 1 and 2. Tables A1÷A8 in Appendix show the organ doses, for all whole-body irradiation geometries investigated.

The values of the effective dose are generally lower than those of the effective dose equivalent. However in the energy range from 10 MeV to 100 MeV, the effective dose is slightly greater than the effective dose equivalent for LAT and ISO irradiation.

Up to about 30-50 MeV, the highest values of the two quantities occur for AP and PA irradiation, while from about 6 MeV the PA values become larger than the AP ones, mainly due to the larger doses received by gonads and breast. On the contrary, at energies greater than 30-50 MeV, the doses for LAT and ISO

Tab. 1 - Fluence-to-Effective Dose Equivalent conversion coefficients (Sv·cm^2) and its statistical uncertainty for different irradiation geometries of an anthropomorphic phantom as a function of the photon energy.

Energy (GeV)	AP		PA		LAT		ISO	
0.00005	4.15E-13	2.18%	3.04E-13	3.27%	1.73E-13	2.05%	2.02E-13	3.28%
0.0001	5.53E-13	1.66%	4.65E-13	2.52%	2.86E-13	2.01%	3.00E-13	3.30%
0.0005	2.59E-12	1.63%	2.30E-12	2.20%	1.66E-12	1.20%	1.74E-12	2.87%
0.001	4.67E-12	2.67%	4.43E-12	2.82%	3.25E-12	2.95%	3.34E-12	4.58%
0.0015	6.35E-12	2.03%	5.85E-12	2.46%	4.64E-12	1.78%	4.91E-12	4.84%
0.002	7.71E-12	1.86%	7.33E-12	3.19%	5.93E-12	1.79%	6.24E-12	3.53%
0.003	1.01E-11	2.08%	9.78E-12	4.97%	8.03E-12	1.71%	8.34E-12	3.62%
0.004	1.24E-11	3.35%	1.18E-11	3.26%	9.90E-12	1.98%	1.07E-11	3.86%
0.005	1.36E-11	2.12%	1.37E-11	3.17%	1.17E-11	2.69%	1.20E-11	4.27%
0.006	1.50E-11	3.18%	1.57E-11	3.17%	1.34E-11	2.07%	1.40E-11	3.64%
0.008	1.78E-11	3.16%	1.89E-11	2.95%	1.67E-11	3.06%	1.69E-11	3.99%
0.01	2.10E-11	3.19%	2.30E-11	3.40%	1.94E-11	2.80%	1.99E-11	2.67%
0.02	3.47E-11	3.91%	3.73E-11	2.54%	3.36E-11	3.52%	3.47E-11	4.84%
0.03	4.80E-11	3.95%	5.26E-11	3.79%	4.65E-11	3.22%	4.82E-11	4.62%
0.04	5.75E-11	3.63%	5.94E-11	2.59%	6.00E-11	2.80%	5.92E-11	4.71%
0.05	6.19E-11	2.54%	7.10E-11	2.37%	7.05E-11	4.22%	6.95E-11	4.41%
0.1	8.13E-11	3.90%	9.53E-11	3.20%	1.17E-10	3.03%	9.98E-11	4.80%
0.2	9.52E-11	3.14%	1.14E-10	4.53%	1.51E-10	2.79%	1.41E-10	3.55%
0.5	1.11E-10	3.53%	1.32E-10	3.61%	1.92E-10	4.70%	1.86E-10	4.66%
1.0	1.22E-10	3.37%	1.43E-10	3.07%	2.18E-10	4.50%	2.05E-10	3.92%
2.0	1.27E-10	3.36%	1.54E-10	3.52%	2.50E-10	4.67%	2.41E-10	3.66%
5.0	1.31E-10	3.84%	1.61E-10	3.11%	2.78E-10	4.11%	2.68E-10	4.27%
10.0	1.33E-10	3.04%	1.64E-10	3.26%	2.92E-10	4.25%	3.00E-10	4.04%

Tab. 2 - Fluence-to-Effective Dose conversion coefficients (Sv·cm^2) and its statistical uncertainty for different irradiation geometries of an anthropomorphic phantom as a function of photon energy.

Energy (GeV)	AP		PA		LAT		ISO	
0.00005	3.68E-13	2.24%	2.35E-13	3.68%	1.23E-13	2.73%	1.69E-13	4.22%
0.0001	5.13E-13	1.35%	4.00E-13	2.47%	2.28E-13	2.13%	2.75E-13	3.43%
0.0005	2.48E-12	1.41%	2.11E-12	2.11%	1.44E-12	1.23%	1.61E-12	3.16%
0.001	4.47E-12	2.41%	4.09E-12	2.70%	2.95E-12	3.08%	3.19E-12	4.49%
0.0015	6.13E-12	1.97%	5.54E-12	2.35%	4.34E-12	1.69%	4.69E-12	4.50%
0.002	7.47E-12	1.69%	6.92E-12	2.95%	5.62E-12	1.76%	5.97E-12	3.78%
0.003	9.94E-12	2.14%	9.28E-12	4.55%	7.77E-12	1.73%	8.11E-12	3.68%
0.004	1.22E-11	3.22%	1.13E-11	2.90%	9.66E-12	2.08%	1.03E-11	3.63%
0.005	1.36E-11	2.04%	1.32E-11	2.65%	1.14E-11	2.66%	1.18E-11	4.11%
0.006	1.52E-11	2.79%	1.50E-11	2.79%	1.33E-11	1.96%	1.37E-11	3.62%
0.008	1.82E-11	2.96%	1.83E-11	2.78%	1.66E-11	2.75%	1.66E-11	3.74%
0.01	2.16E-11	2.83%	2.23E-11	2.96%	1.96E-11	2.66%	2.00E-11	2.55%
0.02	3.44E-11	3.52%	3.66E-11	2.41%	3.47E-11	2.90%	3.48E-11	4.30%
0.03	4.54E-11	3.46%	5.06E-11	3.21%	4.80E-11	2.15%	4.88E-11	4.02%
0.04	5.22E-11	3.31%	5.75E-11	2.36%	6.21E-11	2.31%	5.92E-11	3.92%
0.05	5.55E-11	2.38%	6.72E-11	2.35%	7.37E-11	3.54%	6.89E-11	3.82%
0.1	7.06E-11	3.68%	8.91E-11	3.12%	1.19E-10	2.65%	1.00E-10	4.32%
0.2	8.16E-11	2.99%	1.06E-10	4.15%	1.51E-10	2.63%	1.40E-10	3.20%
0.5	9.37E-11	3.56%	1.21E-10	3.30%	1.90E-10	4.23%	1.81E-10	4.13%
1.0	1.03E-10	3.39%	1.32E-10	2.81%	2.14E-10	4.26%	2.01E-10	3.50%
2.0	1.05E-10	3.27%	1.40E-10	3.39%	2.43E-10	4.06%	2.35E-10	3.21%
5.0	1.07E-10	3.84%	1.46E-10	2.84%	2.69E-10	3.76%	2.64E-10	3.75%
10.0	1.10E-10	3.01%	1.49E-10	2.92%	2.81E-10	3.75%	2.93E-10	3.88%

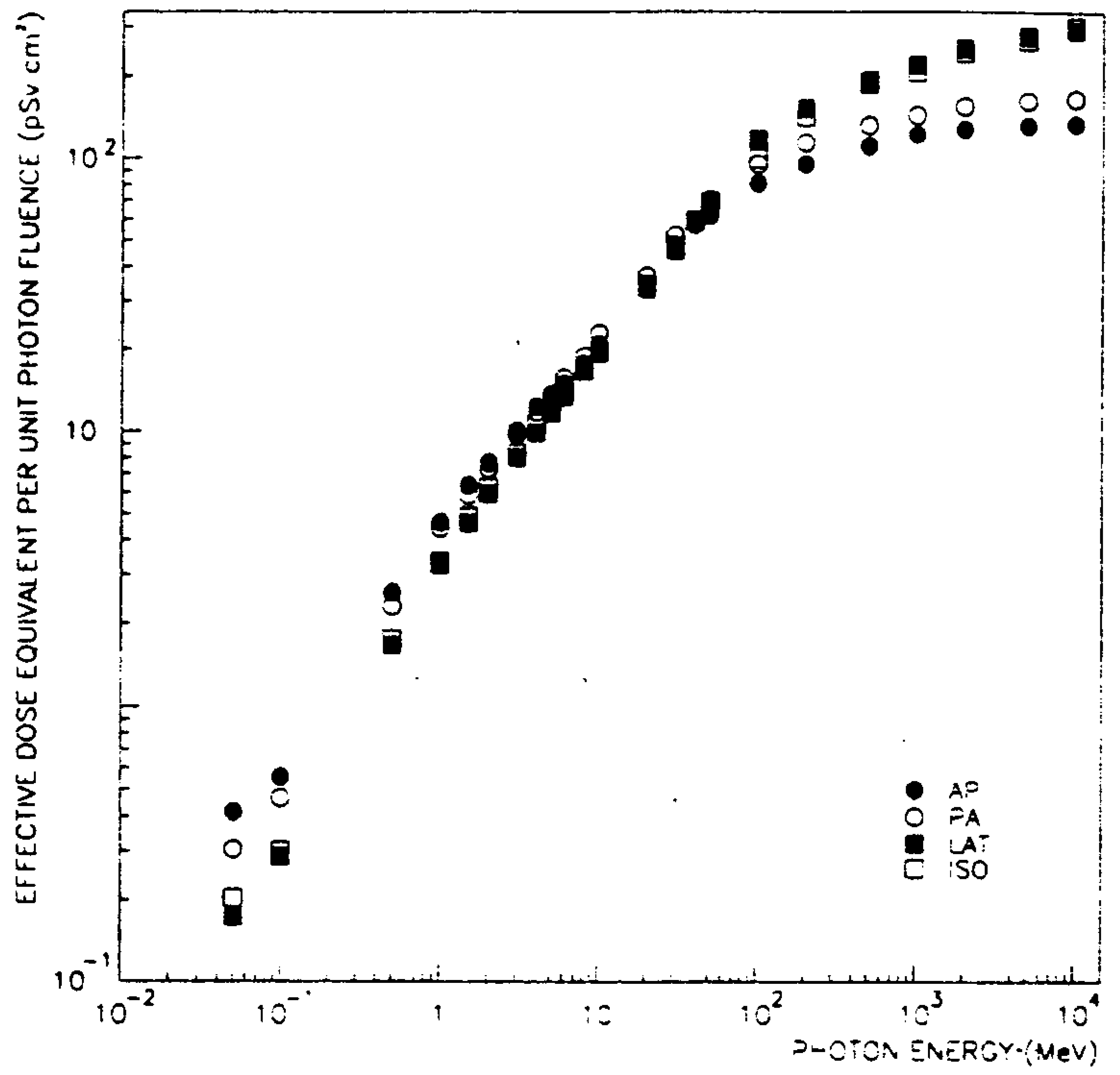

Fig. 1 Effective dose equivalent per unit photon fluence as a function of the photon energy for various irradiation geometries of an anthropomorphic phantom, placed in a vacuum.

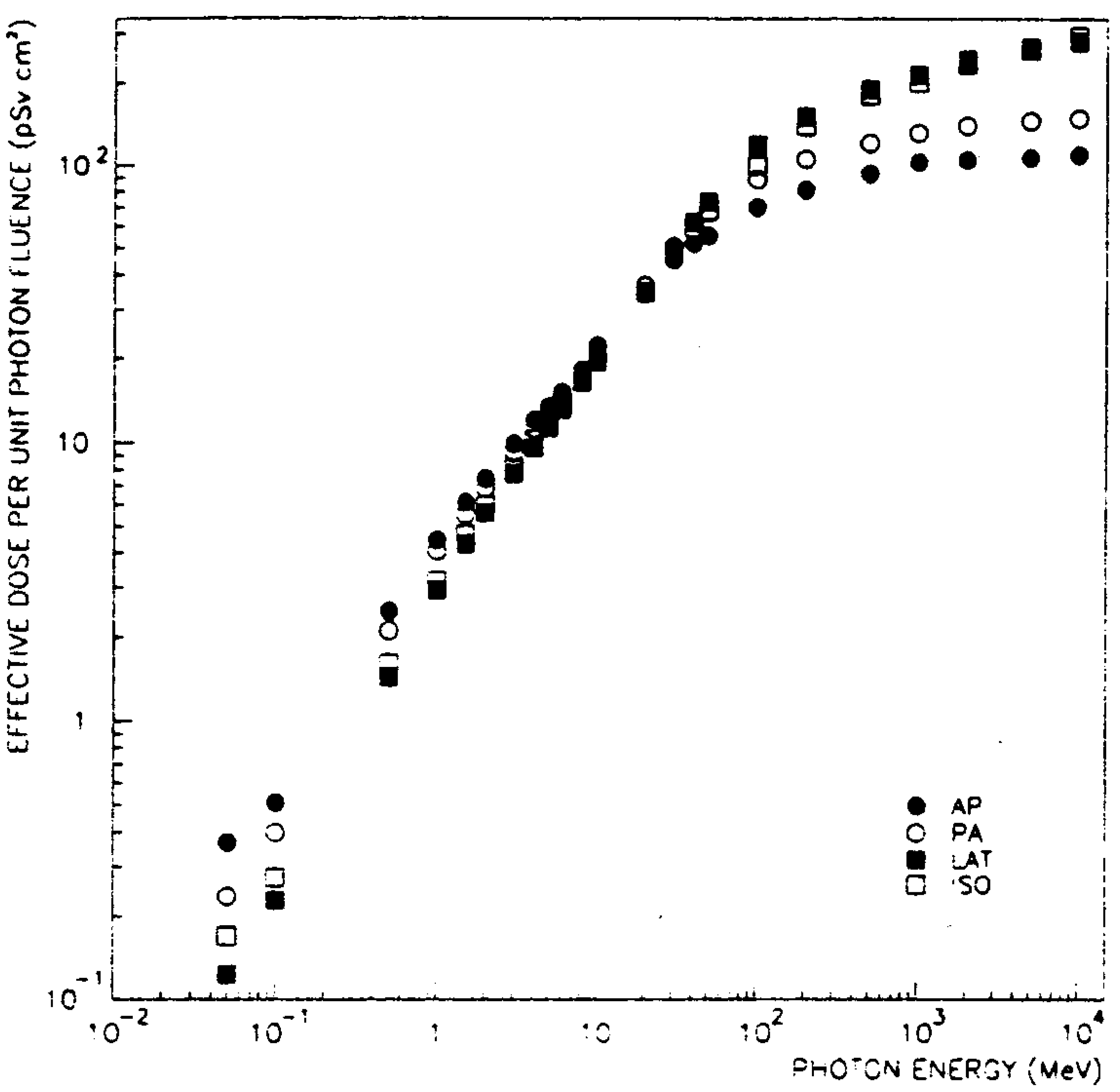

Fig. 2 Effective dose per unit photon fluence as a function of the photon energy for various irradiation geometries of an anthropomorphic phantom, placed in a vacuum.

irradiation are the most important ones. In particular, for a photon energy of 10 GeV, ISO irradiation gives the larger value both for effective dose and effective dose equivalent. In the energy range from 8 MeV to 30-50 MeV only minor differences occur between the values of the doses found for the four geometries investigated.

In the case of the organs and tissues spread throughout the whole body and represented by several regions in the simulation, effective dose and effective dose equivalent have been alternatively evaluated considering the maximum value in the relevant regions. The differences with respect to the values calculated as arithmetic mean, and shown in tab. 1 and 2, are insignificant for ISO irradiation over the whole energy range investigated, for AP and PA irradiation in the energy range 100 keV to 40-50 MeV, and for LAT irradiation from 6 MeV to 50 MeV. Appreciable differences have been found, however, above approximately 40 MeV for AP irradiation, especially in the calculation of the effective dose, when the difference can reach about 7.9% for a photon energy of 5 GeV. In the case of PA irradiation the largest differences occur at 5 GeV for the effective dose (6.6%) and at 10 GeV for the effective dose equivalent (10.6%). For LAT irradiation, remarkable differences concern the effective dose at high photon energy (up to 12.9% at 10 GeV) and both effective dose and effective dose equivalent at low energy, respectively up to 25.1% and 20.8% at 50 keV. These results confirm the need of guidance about the matter.

The agreement between the results of the present study and the values of the conversion coefficients from photon fluence to effective dose equivalent, recommended in ICRP Publication 51 and in ICRU Report 43(15), is generally satisfactory within the statistical uncertainties, at least up to approximately 3 MeV, as shown in tab. 3. To study the reason for the differences found in the energy range 3-10 MeV, an additional simulation has been carried out, in the case of AP irradiation, for an incident photon energy of 10 MeV, with a cut-off electron energy higher than 10 MeV to eliminate the effect of secondary electron transport. The better agreement between the result so obtained (23.0 $pSv \cdot cm^2$) and the values recommended by ICRP and ICRU is an indication that the differences found arise from the kerma approximation applied in the calculations of the International Bodies.

The results of the present paper have been also compared, in tab. 4, with the calculations of ref. (6). The agreement for PA irradiation is very remarkable, since no significant differences

Tab. 3 - Comparison of the results in terms of Effective Dose Equivalent (pSv cm^2) with the values recommended by ICRP (3) and ICRU (15).

Energy (MeV)	AP			PA			LAT			ISO		
	Present work	ICRP	ICRU (*)	Present work	ICRP	ICRU (*)	Present work	ICRP	ICRU (*)	Present work	ICRP	ICRU (*)
0.05	0.415	0.384	0.377	0.304	0.260	0.258	0.173	0.152	0.150	0.202	0.180	0.177
0.1	0.553	0.533	0.551	0.465	0.418	0.398	0.286	0.258	0.258	0.300	0.284	0.288
0.5	2.59	2.54	2.51	2.30	2.20	2.25	1.66	1.58	1.63	1.74	1.64	1.63
1	4.67	4.60	4.71	4.43	4.18	4.32	3.25	3.24	3.48	3.34	3.27	3.48
1.5	6.35	6.24		5.85	5.80		4.64	4.70		4.91	4.68	
2	7.71	7.66		7.33	7.21		5.93	6.02		6.24	5.93	
3	10.1	10.2	10.2	9.78	9.71	9.73	8.03	8.40	9.22	8.34	8.19	8.27
4	12.4	12.5		11.8	12.0		9.90	10.6		10.7	10.2	
5	13.6	14.7		13.7	14.1		11.7	12.6		12.0	12.1	
6	15.0	16.7	17.7	15.7	16.2	15.8	13.4	14.6	15.8	14.0	14.0	14.2
8	17.8	20.8		18.9	20.2		16.7	18.5		16.9	17.8	
10	21.0	24.7	24.4	23.0	24.2	23.1	19.4	22.3	24.4	19.9	21.6	20.8

(*) Data extracted from fig. D.13

Tab. 4 - Comparison of the results in terms of Effective Dose in AP and PA geometries with those of ref. (6).

Energy (GeV)	AP		PA	
	Present work (pSv.cm^2)	Ref. (6) (pSv.cm^2)	Present work (pSv.cm^2)	Ref. (6) (pSv.cm^2)
0.001	4.47 ± 2.4%	4.75 ± 2.2%	4.09 ± 2.7%	3.86 ± 2.2%
0.003	9.94 ± 2.1%	9.95 ± 2.7%	9.28 ± 4.5%	9.43 ± 2.7%
0.005	13.6 ± 1.4%	14.2 ± 2.8%	13.2 ± 2.6%	13.3 ± 2.8%
0.01	21.6 ± 2.4%	21.4 ± 1.1%	22.3 ± 2.9%	21.8 ± 1.1%
0.02	34.4 ± 1.7%	34.5 ± 0.9%	36.6 ± 2.4%	37.7 ± 0.9%
0.05	55.5 ± 2.4%	52.9 ± 0.8%	67.2 ± 2.3%	69.4 ± 0.7%
0.1	70.6 ± 3.7%	65.3 ± 0.8%	89.1 ± 4.1%	91.8 ± 0.6%
0.5	93.7 ± 3.6%	86.9 ± 0.8%	121 ± 3.3%	126.6 ± 0.7%
1.0	103 ± 3.4%	90.9 ± 0.9%	132 ± 2.8%	136.0 ± 0.9%
10.0	110 ± 3.0%	100.9 ± 0.9%	149 ± 2.9%	155.1 ± 0.9%

occur, within the statistical uncertainties, over the whole energy range. The same arises for AP irradiation up to approximately 50-100 MeV. Above 100 MeV, the values of the doses of the present study are systematically higher, up to about 10% for a photon energy of 10 GeV. That seems due to the higher doses estimated for some organs, mainly lungs and breast, for which the differences with respect to the values of ref. (6) can exceed 50%.

At last, a comparison concerning the operational quantities has been performed. The ambient dose equivalent, correctly evaluated as in ref. (16, 17), provides a conservative estimate of the effective dose equivalent and of the effective dose for all geometries investigated only up to 3 MeV. Using the conversion coefficients recommended by ICRU, based on the not appropriate kerma approximation, the conservatism would be extended up to 10 MeV. The maximum dose equivalent is confirmed as a conservative approximation of the limiting quantities over the whole energy range, whatever simplified phantom is chosen for the calculations[18,19].

CONCLUSION

The results of the present paper provide a satisfactory basis for radiation protection dosimetry of high energy photon radiation fields. Next step will be the study of the effect of the air on the doses received by the anthropomorphic phantoms. Very preliminary tests have shown that this effect is practically negligible in the energy range below 10 MeV. On the contrary, remarkable differences with respect to the irradiation in a vacuum have been noted at high energies, especially when the air depth crossed by photon radiation becomes of the order of some tens of meters.

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APPENDIX

Table A1 Organ doses to the principal organs of an anthropomorphic phantom per unit photon fluence incident in AP geometry.

Energy (GeV)	Gonads (Gy.cm2)	BoneMar. (Gy.cm2)	Colon (Gy.cm2)	Lung (Gy.cm2)	Stomach (Gy.cm2)	Bladder (Gy.cm2)	Breast (Gy.cm2)	Liver (Gy.cm2)	Oesoph. (Gy.cm2)	Tyroid (Gy.cm2)	Skin (Gy.cm2)	BoneSur. (Gy.cm2)
0.000050	5.41E-13	1.04E-13	3.50E-13	2.67E-13	4.38E-13	4.44E-13	4.90E-13	3.42E-13	1.57E-13	5.49E-13	5.94E-13	5.03E-13
0.000100	6.48E-13	2.47E-13	5.31E-13	4.17E-13	6.23E-13	6.15E-13	5.97E-13	5.08E-13	3.51E-13	6.52E-13	6.84E-13	6.11E-13
0.000500	2.96E-12	1.75E-12	2.53E-12	2.23E-12	2.73E-12	2.71E-12	2.81E-12	2.46E-12	1.82E-12	3.10E-12	2.91E-12	1.88E-12
0.001000	5.09E-12	3.52E-12	4.49E-12	4.15E-12	4.97E-12	4.50E-12	5.13E-12	4.45E-12	3.49E-12	5.15E-12	3.87E-12	3.53E-12
0.001500	6.82E-12	5.07E-12	6.16E-12	5.90E-12	6.46E-12	6.52E-12	6.93E-12	6.07E-12	5.16E-12	6.98E-12	4.69E-12	5.03E-12
0.002000	8.17E-12	6.46E-12	7.55E-12	7.23E-12	7.97E-12	8.04E-12	8.12E-12	7.49E-12	6.36E-12	8.09E-12	5.25E-12	6.27E-12
0.003000	1.08E-11	8.81E-12	9.86E-12	9.85E-12	1.08E-11	1.02E-11	9.91E-12	9.97E-12	8.23E-12	1.17E-11	6.26E-12	8.67E-12
0.004000	1.41E-11	1.08E-11	1.22E-11	1.20E-11	1.28E-11	1.19E-11	1.09E-11	1.20E-11	1.12E-11	1.38E-11	7.10E-12	1.06E-11
0.005000	1.38E-11	1.27E-11	1.43E-11	1.41E-11	1.46E-11	1.47E-11	1.17E-11	1.41E-11	1.27E-11	1.45E-11	7.86E-12	1.25E-11
0.006000	1.49E-11	1.46E-11	1.60E-11	1.61E-11	1.65E-11	1.59E-11	1.21E-11	1.58E-11	1.44E-11	1.59E-11	8.63E-12	1.43E-11
0.008000	1.74E-11	1.77E-11	2.03E-11	1.98E-11	1.95E-11	2.04E-11	1.20E-11	1.93E-11	1.73E-11	1.77E-11	1.01E-11	1.76E-11
0.010000	2.14E-11	2.14E-11	2.36E-11	2.39E-11	2.26E-11	2.33E-11	1.25E-11	2.31E-11	2.16E-11	2.05E-11	1.15E-11	2.11E-11
0.020000	3.98E-11	3.64E-11	3.76E-11	4.09E-11	2.99E-11	3.18E-11	1.27E-11	3.43E-11	3.77E-11	2.22E-11	1.84E-11	3.58E-11
0.030000	6.06E-11	5.07E-11	4.59E-11	5.30E-11	3.48E-11	3.82E-11	1.19E-11	4.25E-11	5.53E-11	1.89E-11	2.48E-11	4.97E-11
0.040000	7.24E-11	6.25E-11	4.97E-11	6.06E-11	3.64E-11	3.82E-11	1.27E-11	4.76E-11	6.86E-11	1.93E-11	3.14E-11	6.01E-11
0.050000	6.67E-11	7.37E-11	5.37E-11	6.73E-11	3.88E-11	4.15E-11	1.44E-11	5.08E-11	8.00E-11	2.36E-11	3.68E-11	6.98E-11
0.100000	8.89E-11	1.00E-10	6.40E-11	8.60E-11	4.44E-11	5.03E-11	1.49E-11	6.44E-11	9.94E-11	2.48E-11	5.22E-11	9.47E-11
0.200000	9.95E-11	1.23E-10	7.21E-11	9.75E-11	5.20E-11	5.63E-11	1.51E-11	7.29E-11	1.22E-10	2.76E-11	6.49E-11	1.14E-10
0.500000	1.14E-10	1.47E-10	8.00E-11	1.12E-10	5.76E-11	5.96E-11	1.85E-11	8.10E-11	1.45E-10	2.95E-11	7.84E-11	1.35E-10
1.000000	1.36E-10	1.57E-10	8.85E-11	1.18E-10	5.97E-11	6.52E-11	1.87E-11	8.64E-11	1.45E-10	3.87E-11	8.57E-11	1.45E-10
2.000000	1.36E-10	1.68E-10	8.82E-11	1.21E-10	6.08E-11	6.69E-11	1.85E-11	8.77E-11	1.56E-10	3.07E-11	9.22E-11	1.53E-10
5.000000	1.28E-10	1.78E-10	8.93E-11	1.28E-10	6.10E-11	6.96E-11	2.00E-11	9.38E-11	1.66E-10	3.27E-11	9.73E-11	1.62E-10
10.000000	1.29E-10	1.86E-10	9.29E-11	1.29E-10	6.24E-11	7.05E-11	1.95E-11	9.59E-11	1.76E-10	3.46E-11	1.03E-10	1.69E-10

Table A2 Organ doses to the remainder of an anthropomorphic phantom per unit photon fluence incident in AP geometry.

Energy (GeV)	Adrenals (Gy.cm2)	Brain (Gy.cm2)	S.Intest. (Gy.cm2)	Kidney (Gy.cm2)	Muscle (Gy.cm2)	Pancreas (Gy.cm2)	Spleen (Gy.cm2)	Thymus (Gy.cm2)	Uterus (Gy.cm2)
0.000050	1.08E-13	1.79E-13	3.04E-13	9.60E-14	2.74E-13	2.47E-13	1.89E-13	5.60E-13	3.15E-13
0.000100	2.51E-13	3.05E-13	4.98E-13	2.30E-13	4.07E-13	4.50E-13	3.44E-13	6.61E-13	5.25E-13
0.000500	1.59E-12	1.90E-12	2.36E-12	1.52E-12	2.20E-12	2.26E-12	1.96E-12	2.80E-12	2.43E-12
0.001000	3.23E-12	3.75E-12	4.34E-12	3.19E-12	4.14E-12	4.20E-12	3.83E-12	5.30E-12	4.35E-12
0.001500	5.09E-12	5.33E-12	5.93E-12	4.50E-12	5.73E-12	5.68E-12	5.29E-12	6.73E-12	5.76E-12
0.002000	5.94E-12	6.72E-12	7.20E-12	5.90E-12	7.11E-12	7.05E-12	6.67E-12	7.90E-12	7.42E-12
0.003000	8.35E-12	9.18E-12	9.60E-12	8.32E-12	9.42E-12	9.51E-12	8.64E-12	1.04E-11	9.47E-12
0.004000	1.00E-11	1.11E-11	1.19E-11	1.03E-11	1.13E-11	1.03E-11	1.10E-11	1.21E-11	1.16E-11
0.005000	1.24E-11	1.33E-11	1.37E-11	1.19E-11	1.31E-11	1.26E-11	1.30E-11	1.51E-11	1.36E-11
0.006000	1.35E-11	1.52E-11	1.55E-11	1.38E-11	1.47E-11	1.54E-11	1.48E-11	1.67E-11	1.53E-11
0.008000	1.67E-11	1.85E-11	1.96E-11	1.73E-11	1.75E-11	1.84E-11	1.85E-11	1.94E-11	1.93E-11
0.010000	2.11E-11	2.25E-11	2.28E-11	2.08E-11	2.01E-11	2.22E-11	2.30E-11	2.00E-11	2.26E-11
0.020000	3.48E-11	3.74E-11	3.85E-11	3.75E-11	3.16E-11	3.96E-11	3.97E-11	2.12E-11	3.89E-11
0.030000	5.70E-11	4.95E-11	4.99E-11	5.60E-11	3.99E-11	5.36E-11	5.49E-11	2.21E-11	4.67E-11
0.040000	7.32E-11	5.56E-11	5.51E-11	7.06E-11	4.66E-11	6.18E-11	6.48E-11	2.34E-11	5.58E-11
0.050000	8.24E-11	6.31E-11	5.98E-11	8.57E-11	5.22E-11	6.67E-11	7.41E-11	2.29E-11	5.69E-11
0.100000	1.14E-10	8.22E-11	7.28E-11	1.17E-10	6.75E-11	8.90E-11	9.63E-11	2.43E-11	7.17E-11
0.200000	1.36E-10	9.43E-11	8.66E-11	1.48E-10	8.08E-11	9.88E-11	1.18E-10	2.98E-11	8.59E-11
0.500000	1.73E-10	1.11E-10	9.61E-11	1.75E-10	9.35E-11	1.07E-10	1.29E-10	3.64E-11	9.88E-11
1.000000	1.81E-10	1.18E-10	1.06E-10	1.91E-10	1.01E-10	1.15E-10	1.37E-10	3.44E-11	9.82E-11
2.000000	1.96E-10	1.22E-10	1.07E-10	2.07E-10	1.06E-10	1.34E-10	1.45E-10	3.54E-11	9.91E-11
5.000000	2.15E-10	1.30E-10	1.08E-10	2.21E-10	1.12E-10	1.28E-10	1.54E-10	3.41E-11	1.07E-10
10.000000	2.05E-10	1.33E-10	1.16E-10	2.23E-10	1.16E-10	1.27E-10	1.58E-10	3.38E-11	1.08E-10

Table A3 Organ doses to the principal organs of an anthropomorphic phantom per unit photon fluence incident in PA geometry.

Energy (GeV)	Gonads (Gy.cm2)	BoneMar. (Gy.cm2)	Colon (Gy.cm2)	Lung (Gy.cm2)	Stomach (Gy.cm2)	Bladder (Gy.cm2)	Breast (Gy.cm2)	Liver (Gy.cm2)	Oesoph. (Gy.cm2)	Tyroid (Gy.cm2)	Skin (Gy.cm2)	BoneSur. (Gy.cm2)
0.000050	2.78E-13	2.44E-13	1.78E-13	4.06E-13	1.55E-13	1.31E-13	7.62E-14	2.33E-13	2.42E-13	8.56E-14	3.27E-13	1.01E-12
0.000100	4.55E-13	4.47E-13	3.62E-13	5.60E-13	2.95E-13	2.83E-13	1.93E-13	3.95E-13	4.93E-13	2.06E-13	4.20E-13	9.47E-13
0.000500	2.23E-12	2.45E-12	1.98E-12	2.68E-12	1.75E-12	1.73E-12	1.57E-12	2.08E-12	2.37E-12	1.41E-12	2.32E-12	2.47E-12
0.001000	4.80E-12	4.46E-12	3.77E-12	4.79E-12	3.47E-12	3.41E-12	3.42E-12	3.93E-12	4.09E-12	2.94E-12	3.85E-12	4.41E-12
0.001500	5.62E-12	6.17E-12	5.34E-12	6.58E-12	5.01E-12	4.95E-12	4.93E-12	5.48E-12	5.85E-12	4.57E-12	4.65E-12	5.95E-12
0.002000	7.08E-12	7.62E-12	6.69E-12	8.09E-12	6.28E-12	5.84E-12	6.42E-12	6.88E-12	6.98E-12	6.28E-12	5.38E-12	7.35E-12
0.003000	9.54E-12	1.02E-11	8.68E-12	1.06E-11	8.71E-12	8.46E-12	8.66E-12	9.19E-12	9.41E-12	8.53E-12	7.52E-12	9.60E-12
0.004000	1.14E-11	1.23E-11	1.12E-11	1.29E-11	1.07E-11	1.09E-11	1.07E-11	1.13E-11	1.20E-11	9.67E-12	9.90E-12	1.17E-11
0.005000	1.29E-11	1.44E-11	1.30E-11	1.51E-11	1.27E-11	1.25E-11	1.25E-11	1.33E-11	1.40E-11	1.22E-11	1.24E-11	1.37E-11
0.006000	1.50E-11	1.61E-11	1.47E-11	1.71E-11	1.40E-11	1.51E-11	1.44E-11	1.50E-11	1.53E-11	1.26E-11	1.45E-11	1.55E-11
0.008000	1.84E-11	1.95E-11	1.82E-11	2.05E-11	1.80E-11	1.69E-11	1.73E-11	1.90E-11	2.06E-11	1.39E-11	1.65E-11	1.88E-11
0.010000	2.47E-11	2.22E-11	2.18E-11	2.35E-11	2.16E-11	2.09E-11	2.12E-11	2.20E-11	2.31E-11	2.15E-11	2.16E-11	2.15E-11
0.020000	3.76E-11	3.21E-11	3.95E-11	3.31E-11	3.96E-11	3.82E-11	3.81E-11	3.72E-11	4.16E-11	3.92E-11	3.87E-11	3.23E-11
0.030000	6.18E-11	3.79E-11	5.47E-11	3.61E-11	5.61E-11	5.57E-11	5.70E-11	4.97E-11	5.36E-11	5.20E-11	5.77E-11	3.87E-11
0.040000	6.28E-11	4.20E-11	6.68E-11	3.77E-11	6.69E-11	7.05E-11	6.85E-11	5.72E-11	6.06E-11	6.79E-11	8.04E-11	4.30E-11
0.050000	8.03E-11	4.64E-11	7.63E-11	4.10E-11	7.78E-11	8.01E-11	8.10E-11	6.55E-11	6.43E-11	8.31E-11	1.02E-10	4.69E-11
0.100000	1.08E-10	5.82E-11	1.00E-10	4.75E-11	1.05E-10	1.09E-10	1.11E-10	8.76E-11	7.95E-11	1.24E-10	1.58E-10	5.87E-11
0.200000	1.35E-10	6.46E-11	1.17E-10	5.20E-11	1.24E-10	1.35E-10	1.31E-10	1.04E-10	9.51E-11	1.47E-10	2.13E-10	6.61E-11
0.500000	1.38E-10	7.38E-11	1.33E-10	5.59E-11	1.55E-10	1.65E-10	1.51E-10	1.22E-10	1.10E-10	1.90E-10	2.58E-10	7.47E-11
1.000000	1.61E-10	7.84E-11	1.46E-10	5.89E-11	1.66E-10	1.81E-10	1.64E-10	1.28E-10	1.16E-10	1.94E-10	2.91E-10	8.04E-11
2.000000	1.77E-10	8.15E-11	1.51E-10	6.13E-11	1.78E-10	1.82E-10	1.72E-10	1.30E-10	1.16E-10	2.27E-10	3.30E-10	8.30E-11
5.000000	1.82E-10	8.58E-11	1.59E-10	6.35E-11	1.83E-10	1.98E-10	1.84E-10	1.39E-10	1.17E-10	2.18E-10	3.50E-10	8.54E-11
10.000000	1.73E-10	8.65E-11	1.62E-10	6.37E-11	1.93E-10	2.03E-10	1.85E-10	1.42E-10	1.25E-10	2.64E-10	3.70E-10	8.68E-11

Table A4 Organ doses to the remainder of an anthropomorphic phantom per unit photon fluence incident in PA geometry.

Energy (GeV)	Adrenals (Gy.cm2)	Brain (Gy.cm2)	S.Intest. (Gy.cm2)	Kidney (Gy.cm2)	Muscle (Gy.cm2)	Pancreas (Gy.cm2)	Spleen (Gy.cm2)	Thymus (Gy.cm2)	Uterus (Gy.cm2)
0.000050	4.07E-13	1.87E-13	2.13E-13	4.95E-13	2.80E-13	2.23E-13	3.99E-13	6.71E-14	1.84E-13
0.000100	6.09E-13	3.16E-13	4.11E-13	6.60E-13	4.13E-13	4.45E-13	5.74E-13	1.88E-13	3.91E-13
0.000500	2.83E-12	1.93E-12	2.08E-12	2.92E-12	2.23E-12	2.14E-12	2.65E-12	1.24E-12	2.02E-12
0.001000	4.99E-12	3.76E-12	3.99E-12	5.07E-12	4.18E-12	3.72E-12	4.80E-12	2.71E-12	3.95E-12
0.001500	6.36E-12	5.30E-12	5.56E-12	6.74E-12	5.79E-12	5.50E-12	6.33E-12	4.20E-12	5.31E-12
0.002000	7.98E-12	6.69E-12	6.92E-12	8.21E-12	7.18E-12	7.17E-12	7.90E-12	5.23E-12	6.77E-12
0.003000	1.04E-11	9.13E-12	9.10E-12	1.09E-11	9.48E-12	8.62E-12	1.08E-11	7.88E-12	8.98E-12
0.004000	1.23E-11	1.13E-11	1.14E-11	1.26E-11	1.14E-11	1.11E-11	1.23E-11	9.39E-12	1.12E-11
0.005000	1.40E-11	1.33E-11	1.32E-11	1.52E-11	1.32E-11	1.35E-11	1.51E-11	1.08E-11	1.30E-11
0.006000	1.79E-11	1.53E-11	1.51E-11	1.71E-11	1.47E-11	1.56E-11	1.67E-11	1.30E-11	1.47E-11
0.008000	2.13E-11	1.88E-11	1.85E-11	1.85E-11	1.76E-11	1.80E-11	1.96E-11	1.71E-11	1.79E-11
0.010000	2.30E-11	2.22E-11	2.20E-11	2.17E-11	2.02E-11	2.26E-11	2.35E-11	1.78E-11	2.19E-11
0.020000	3.07E-11	3.67E-11	4.01E-11	2.40E-11	3.12E-11	3.78E-11	3.43E-11	3.46E-11	4.10E-11
0.030000	3.06E-11	4.74E-11	5.38E-11	2.41E-11	3.94E-11	5.61E-11	3.96E-11	5.18E-11	5.83E-11
0.040000	3.88E-11	5.53E-11	6.23E-11	2.62E-11	4.57E-11	6.47E-11	4.00E-11	6.78E-11	6.96E-11
0.050000	4.23E-11	6.23E-11	7.19E-11	2.69E-11	5.10E-11	6.79E-11	4.24E-11	8.52E-11	7.66E-11
0.100000	4.88E-11	7.95E-11	9.22E-11	3.00E-11	6.53E-11	9.77E-11	4.87E-11	1.30E-10	9.65E-11
0.200000	5.94E-11	9.34E-11	1.11E-10	3.41E-11	7.80E-11	1.16E-10	5.56E-11	1.62E-10	1.18E-10
0.500000	5.36E-11	1.06E-10	1.23E-10	3.83E-11	9.11E-11	1.15E-10	6.09E-11	2.14E-10	1.44E-10
1.000000	5.15E-11	1.15E-10	1.34E-10	3.87E-11	9.70E-11	1.32E-10	6.44E-11	2.21E-10	1.33E-10
2.000000	6.38E-11	1.20E-10	1.42E-10	3.96E-11	1.04E-10	1.30E-10	6.84E-11	2.60E-10	1.50E-10
5.000000	7.20E-11	1.29E-10	1.48E-10	4.09E-11	1.09E-10	1.49E-10	6.77E-11	2.57E-10	1.66E-10
10.000000	7.16E-11	1.32E-10	1.53E-10	4.02E-11	1.11E-10	1.50E-10	7.08E-11	3.05E-10	1.68E-10

Table A5 Organ doses to the principal organs of an anthropomorphic phantom per unit photon fluence incident in LAT geometry.

Energy (GeV)	Gonads (Gy.cm2)	BoneMar. (Gy.cm2)	Colon (Gy.cm2)	Lung (Gy.cm2)	Stomach (Gy.cm2)	Bladder (Gy.cm2)	Breast (Gy.cm2)	Liver (Gy.cm2)	Oesoph. (Gy.cm2)	Tyroid (Gy.cm2)	Skin (Gy.cm2)	BoneSur. (Gy.cm2)
0.000050	7.33E-14	1.13E-13	8.21E-14	2.46E-13	1.77E-14	7.16E-14	2.26E-13	2.23E-13	6.90E-14	2.49E-13	3.01E-13	4.48E-13
0.000100	1.73E-13	2.46E-13	1.73E-13	3.87E-13	6.65E-14	1.74E-13	3.03E-13	3.69E-13	1.89E-13	4.12E-13	4.34E-13	4.84E-13
0.000500	1.19E-12	1.70E-12	1.15E-12	2.11E-12	7.27E-13	1.26E-12	1.56E-12	1.99E-12	1.43E-12	2.34E-12	2.94E-12	1.63E-12
0.001000	2.56E-12	3.44E-12	2.52E-12	4.08E-12	1.76E-12	2.67E-12	2.85E-12	3.88E-12	3.03E-12	4.35E-12	5.57E-12	3.20E-12
0.001500	3.99E-12	4.93E-12	3.74E-12	5.70E-12	2.90E-12	4.24E-12	3.57E-12	5.41E-12	4.56E-12	6.35E-12	6.62E-12	4.62E-12
0.002000	5.48E-12	6.36E-12	5.00E-12	6.96E-12	3.93E-12	5.36E-12	4.34E-12	6.75E-12	5.75E-12	7.94E-12	7.10E-12	5.81E-12
0.003000	7.52E-12	8.60E-12	7.05E-12	9.44E-12	5.94E-12	7.83E-12	5.60E-12	9.13E-12	8.32E-12	1.06E-11	8.93E-12	8.04E-12
0.004000	9.51E-12	1.07E-11	9.00E-12	1.17E-11	7.57E-12	9.67E-12	6.54E-12	1.13E-11	1.00E-11	1.26E-11	9.86E-12	1.01E-11
0.005000	1.10E-11	1.24E-11	1.07E-11	1.38E-11	9.25E-12	1.16E-11	7.18E-12	1.31E-11	1.12E-11	1.51E-11	1.12E-11	1.19E-11
0.006000	1.35E-11	1.43E-11	1.23E-11	1.58E-11	1.14E-11	1.31E-11	7.55E-12	1.49E-11	1.44E-11	1.61E-11	1.20E-11	1.35E-11
0.008000	1.79E-11	1.74E-11	1.56E-11	1.96E-11	1.42E-11	1.64E-11	8.84E-12	1.87E-11	1.71E-11	2.03E-11	1.45E-11	1.69E-11
0.010000	2.01E-11	2.06E-11	1.88E-11	2.32E-11	1.71E-11	2.00E-11	9.53E-12	2.21E-11	2.02E-11	2.40E-11	1.76E-11	1.99E-11
0.020000	3.76E-11	3.49E-11	3.50E-11	4.02E-11	3.28E-11	3.54E-11	1.26E-11	3.74E-11	3.75E-11	3.74E-11	2.53E-11	3.43E-11
0.030000	5.29E-11	4.68E-11	4.93E-11	5.26E-11	4.86E-11	5.20E-11	1.32E-11	4.89E-11	5.52E-11	4.80E-11	3.67E-11	4.57E-11
0.040000	7.32E-11	5.75E-11	6.46E-11	7.03E-11	6.36E-11	6.78E-11	1.41E-11	5.67E-11	6.99E-11	5.38E-11	4.74E-11	5.60E-11
0.050000	8.20E-11	6.70E-11	7.68E-11	8.89E-11	8.09E-11	8.26E-11	1.57E-11	6.29E-11	8.12E-11	6.46E-11	5.75E-11	6.56E-11
0.100000	1.50E-10	9.49E-11	1.28E-10	1.46E-10	1.43E-10	1.24E-10	1.65E-11	8.34E-11	1.23E-10	7.02E-11	9.07E-11	9.59E-11
0.200000	1.81E-10	1.18E-10	1.69E-10	1.94E-10	2.03E-10	1.53E-10	1.98E-11	9.94E-11	1.46E-10	6.54E-11	1.22E-10	1.23E-10
0.500000	2.19E-10	1.44E-10	2.21E-10	2.42E-10	2.78E-10	1.90E-10	2.07E-11	1.14E-10	1.69E-10	7.84E-11	1.58E-10	1.54E-10
1.000000	2.65E-10	1.58E-10	2.42E-10	2.67E-10	3.14E-10	2.07E-10	1.91E-11	1.18E-10	1.91E-10	7.70E-11	1.81E-10	1.71E-10
2.000000	3.11E-10	1.74E-10	2.73E-10	2.98E-10	3.61E-10	2.23E-10	2.06E-11	1.28E-10	2.07E-10	8.41E-11	2.02E-10	1.88E-10
5.000000	3.37E-10	1.88E-10	3.14E-10	3.32E-10	4.11E-10	2.56E-10	2.11E-11	1.37E-10	2.13E-10	8.36E-11	2.26E-10	2.09E-10
10.000000	3.37E-10	1.99E-10	3.41E-10	3.51E-10	4.40E-10	2.52E-10	2.23E-11	1.41E-10	2.28E-10	8.59E-11	2.44E-10	2.23E-10

Table A6 Organ doses to the remainder of an anthropomorphic phantom per unit photon fluence incident in LAT geometry.

Energy (GeV)	Adrenals (Gy.cm2)	Brain (Gy.cm2)	S.Intest. (Gy.cm2)	Kidney (Gy.cm2)	Muscle (Gy.cm2)	Pancreas (Gy.cm2)	Spleen (Gy.cm2)	Thymus (Gy.cm2)	Uterus (Gy.cm2)
0.000050	7.52E-14	2.40E-13	7.33E-14	1.11E-13	1.30E-13	4.68E-14	1.06E-14	9.22E-14	5.76E-14
0.000100	1.73E-13	3.82E-13	1.69E-13	2.05E-13	2.11E-13	1.44E-13	4.27E-14	1.76E-13	1.53E-13
0.000500	1.19E-12	2.18E-12	1.16E-12	1.42E-12	1.40E-12	1.07E-12	5.50E-13	1.44E-12	1.15E-12
0.001000	2.47E-12	4.14E-12	2.51E-12	3.03E-12	2.91E-12	2.32E-12	1.54E-12	3.04E-12	2.48E-12
0.001500	4.16E-12	5.75E-12	3.82E-12	4.43E-12	4.27E-12	3.41E-12	2.42E-12	4.34E-12	3.75E-12
0.002000	5.51E-12	7.26E-12	4.98E-12	5.65E-12	5.49E-12	4.91E-12	3.35E-12	6.02E-12	5.01E-12
0.003000	7.17E-12	9.75E-12	7.15E-12	7.83E-12	7.62E-12	6.48E-12	5.18E-12	7.88E-12	7.07E-12
0.004000	9.85E-12	1.18E-11	8.93E-12	9.95E-12	9.55E-12	8.19E-12	7.06E-12	9.58E-12	8.95E-12
0.005000	1.19E-11	1.40E-11	1.08E-11	1.18E-11	1.12E-11	1.06E-11	8.79E-12	1.28E-11	1.03E-11
0.006000	1.35E-11	1.58E-11	1.26E-11	1.34E-11	1.29E-11	1.19E-11	1.03E-11	1.46E-11	1.25E-11
0.008000	1.68E-11	1.92E-11	1.57E-11	1.69E-11	1.59E-11	1.51E-11	1.24E-11	1.73E-11	1.58E-11
0.010000	2.02E-11	2.26E-11	1.89E-11	2.02E-11	1.87E-11	1.88E-11	1.63E-11	1.99E-11	1.86E-11
0.020000	3.49E-11	3.58E-11	3.53E-11	3.68E-11	3.20E-11	3.54E-11	3.04E-11	3.65E-11	3.48E-11
0.030000	5.42E-11	4.33E-11	5.04E-11	5.05E-11	4.36E-11	5.57E-11	4.61E-11	5.52E-11	4.91E-11
0.040000	6.57E-11	4.87E-11	6.70E-11	6.05E-11	5.45E-11	6.83E-11	6.04E-11	6.48E-11	6.87E-11
0.050000	8.01E-11	5.35E-11	7.92E-11	7.52E-11	6.51E-11	8.02E-11	8.02E-11	8.69E-11	8.46E-11
0.100000	1.26E-10	6.56E-11	1.27E-10	1.08E-10	1.01E-10	1.43E-10	1.48E-10	1.02E-10	1.38E-10
0.200000	1.48E-10	7.49E-11	1.71E-10	1.42E-10	1.35E-10	2.02E-10	2.26E-10	1.23E-10	1.70E-10
0.500000	2.06E-10	8.44E-11	2.20E-10	1.81E-10	1.78E-10	2.53E-10	3.26E-10	1.54E-10	2.16E-10
1.000000	2.15E-10	9.04E-11	2.43E-10	2.02E-10	1.98E-10	2.78E-10	3.59E-10	1.86E-10	2.57E-10
2.000000	2.37E-10	9.57E-11	2.73E-10	2.21E-10	2.23E-10	2.89E-10	4.56E-10	1.98E-10	2.79E-10
5.000000	2.73E-10	9.78E-11	3.09E-10	2.35E-10	2.50E-10	3.42E-10	5.18E-10	1.97E-10	2.97E-10
10.000000	2.66E-10	9.79E-11	3.30E-10	2.41E-10	2.68E-10	3.74E-10	5.57E-10	2.13E-10	3.11E-10

Table A7 Organ doses to the principal organs of an anthropomorphic phantom per unit photon fluence incident in ISO geometry.

Energy (GeV)	Gonads (Gy.cm2)	BoneMar. (Gy.cm2)	Colon (Gy.cm2)	Lung (Gy.cm2)	Stomach (Gy.cm2)	Bladder (Gy.cm2)	Breast (Gy.cm2)	Liver (Gy.cm2)	Oesoph. (Gy.cm2)	Tyroid (Gy.cm2)	Skin (Gy.cm2)	BoneSur. (Gy.cm2)
0.000050	2.07E-13	1.19E-13	1.34E-13	1.82E-13	1.57E-13	1.58E-13	2.43E-13	1.57E-13	1.17E-13	1.67E-13	2.95E-13	4.91E-13
0.000100	2.74E-13	2.49E-13	2.41E-13	2.99E-13	2.82E-13	2.61E-13	3.27E-13	2.72E-13	2.46E-13	3.23E-13	3.43E-13	5.20E-13
0.000500	1.71E-12	1.68E-12	1.48E-12	1.71E-12	1.56E-12	1.38E-12	1.93E-12	1.54E-12	1.53E-12	1.36E-12	2.01E-12	1.64E-12
0.001000	3.15E-12	3.34E-12	2.98E-12	3.41E-12	3.14E-12	3.15E-12	3.52E-12	3.16E-12	2.97E-12	3.23E-12	3.49E-12	3.14E-12
0.001500	5.08E-12	4.81E-12	4.28E-12	4.97E-12	4.52E-12	4.33E-12	5.13E-12	4.49E-12	4.45E-12	4.54E-12	4.38E-12	4.55E-12
0.002000	6.29E-12	6.11E-12	5.51E-12	6.18E-12	5.89E-12	5.65E-12	6.63E-12	5.82E-12	5.30E-12	6.68E-12	4.97E-12	5.72E-12
0.003000	7.93E-12	8.48E-12	7.82E-12	8.61E-12	7.99E-12	7.67E-12	8.57E-12	8.10E-12	8.12E-12	9.09E-12	6.17E-12	8.03E-12
0.004000	1.12E-11	1.06E-11	9.66E-12	1.04E-11	9.97E-12	9.18E-12	1.02E-11	9.96E-12	9.71E-12	1.15E-11	6.84E-12	9.99E-12
0.005000	1.14E-11	1.22E-11	1.13E-11	1.23E-11	1.23E-11	1.08E-11	1.17E-11	1.21E-11	1.14E-11	1.35E-11	7.90E-12	1.16E-11
0.006000	1.40E-11	1.39E-11	1.33E-11	1.45E-11	1.36E-11	1.35E-11	1.27E-11	1.39E-11	1.36E-11	1.40E-11	8.53E-12	1.34E-11
0.008000	1.58E-11	1.72E-11	1.70E-11	1.83E-11	1.68E-11	1.74E-11	1.45E-11	1.70E-11	1.87E-11	1.52E-11	1.03E-11	1.66E-11
0.010000	2.01E-11	2.04E-11	2.01E-11	2.16E-11	2.02E-11	1.96E-11	1.66E-11	2.02E-11	2.03E-11	2.08E-11	1.19E-11	1.97E-11
0.020000	3.78E-11	3.36E-11	3.62E-11	3.79E-11	3.58E-11	3.31E-11	2.38E-11	3.51E-11	3.59E-11	3.17E-11	2.16E-11	3.31E-11
0.030000	5.60E-11	4.48E-11	5.12E-11	4.89E-11	4.96E-11	4.78E-11	3.23E-11	4.71E-11	5.16E-11	5.14E-11	2.83E-11	4.45E-11
0.040000	6.72E-11	5.56E-11	6.30E-11	5.98E-11	5.78E-11	6.26E-11	3.89E-11	5.82E-11	6.67E-11	5.41E-11	3.80E-11	5.52E-11
0.050000	7.62E-11	6.49E-11	7.30E-11	7.06E-11	6.55E-11	7.22E-11	4.45E-11	6.97E-11	7.77E-11	7.01E-11	4.85E-11	6.43E-11
0.100000	1.02E-10	9.28E-11	1.11E-10	1.02E-10	1.04E-10	1.11E-10	7.37E-11	1.02E-10	1.17E-10	9.30E-11	8.23E-11	9.18E-11
0.200000	1.66E-10	1.23E-10	1.52E-10	1.31E-10	1.48E-10	1.47E-10	9.74E-11	1.37E-10	1.49E-10	1.06E-10	1.15E-10	1.22E-10
0.500000	2.31E-10	1.60E-10	1.98E-10	1.58E-10	1.74E-10	1.97E-10	1.32E-10	1.74E-10	1.82E-10	1.56E-10	1.47E-10	1.61E-10
1.000000	2.35E-10	1.80E-10	2.22E-10	1.82E-10	2.07E-10	2.19E-10	1.56E-10	1.99E-10	2.18E-10	1.57E-10	1.98E-10	1.83E-10
2.000000	2.88E-10	2.08E-10	2.54E-10	2.02E-10	2.35E-10	2.49E-10	1.85E-10	2.29E-10	2.52E-10	2.05E-10	2.31E-10	2.09E-10
5.000000	2.94E-10	2.45E-10	3.02E-10	2.34E-10	2.63E-10	3.00E-10	2.06E-10	2.71E-10	2.68E-10	2.37E-10	2.64E-10	2.47E-10
10.000000	3.42E-10	2.68E-10	3.22E-10	2.51E-10	2.93E-10	3.26E-10	2.41E-10	2.98E-10	3.03E-10	2.66E-10	2.69E-10	2.70E-10

Table A8 Organ doses to the remainder of an anthropomorphic phantom per unit photon fluence incident in ISO geometry.

Energy (GeV)	Adrenals (Gy.cm2)	Brain (Gy.cm2)	S.Intest. (Gy.cm2)	Kidney (Gy.cm2)	Muscle (Gy.cm2)	Pancreas (Gy.cm2)	Spleen (Gy.cm2)	Thymus (Gy.cm2)	Uterus (Gy.cm2)
0.000050	1.12E-13	1.87E-13	1.23E-13	1.71E-13	1.96E-13	1.08E-13	1.60E-13	1.55E-13	1.24E-13
0.000100	2.15E-13	3.09E-13	2.44E-13	2.66E-13	2.93E-13	2.43E-13	2.79E-13	2.95E-13	2.31E-13
0.000500	1.51E-12	1.86E-12	1.42E-12	1.61E-12	1.74E-12	1.39E-12	1.56E-12	1.68E-12	1.43E-12
0.001000	3.18E-12	3.64E-12	2.89E-12	3.05E-12	3.45E-12	2.65E-12	3.28E-12	3.30E-12	2.99E-12
0.001500	4.23E-12	5.20E-12	4.28E-12	4.49E-12	4.91E-12	4.11E-12	4.56E-12	4.42E-12	4.26E-12
0.002000	5.95E-12	6.52E-12	5.44E-12	5.78E-12	6.20E-12	5.65E-12	5.49E-12	5.21E-12	5.62E-12
0.003000	8.28E-12	8.97E-12	7.59E-12	7.94E-12	8.39E-12	6.65E-12	7.91E-12	8.02E-12	7.43E-12
0.004000	1.05E-11	1.10E-11	9.39E-12	1.01E-11	1.03E-11	9.09E-12	1.04E-11	1.17E-11	9.83E-12
0.005000	1.14E-11	1.28E-11	1.13E-11	1.16E-11	1.20E-11	1.22E-11	1.17E-11	1.21E-11	1.23E-11
0.006000	1.38E-11	1.51E-11	1.30E-11	1.41E-11	1.35E-11	1.33E-11	1.36E-11	1.50E-11	1.35E-11
0.008000	1.47E-11	1.84E-11	1.68E-11	1.68E-11	1.65E-11	1.66E-11	1.75E-11	1.64E-11	1.71E-11
0.010000	1.96E-11	2.13E-11	1.98E-11	2.00E-11	1.92E-11	1.99E-11	2.02E-11	2.00E-11	1.99E-11
0.020000	3.33E-11	3.51E-11	3.62E-11	3.21E-11	3.13E-11	3.94E-11	3.52E-11	3.30E-11	3.52E-11
0.030000	4.99E-11	4.45E-11	5.05E-11	4.18E-11	4.18E-11	4.93E-11	5.01E-11	4.54E-11	5.02E-11
0.040000	5.90E-11	5.36E-11	6.17E-11	5.33E-11	5.07E-11	6.57E-11	5.75E-11	5.45E-11	6.28E-11
0.050000	7.77E-11	5.96E-11	7.67E-11	6.39E-11	5.87E-11	7.37E-11	6.96E-11	6.24E-11	7.90E-11
0.100000	9.51E-11	8.07E-11	1.13E-10	1.02E-10	8.64E-11	1.15E-10	1.01E-10	9.65E-11	1.13E-10
0.200000	1.59E-10	9.74E-11	1.54E-10	1.37E-10	1.15E-10	1.65E-10	1.36E-10	1.26E-10	1.64E-10
0.500000	1.71E-10	1.23E-10	1.94E-10	1.75E-10	1.45E-10	1.97E-10	1.76E-10	1.60E-10	2.17E-10
1.000000	2.05E-10	1.36E-10	2.31E-10	2.07E-10	1.67E-10	2.30E-10	2.13E-10	1.84E-10	2.31E-10
2.000000	2.17E-10	1.59E-10	2.60E-10	2.27E-10	1.90E-10	2.65E-10	2.28E-10	2.14E-10	2.68E-10
5.000000	2.90E-10	1.79E-10	2.94E-10	2.70E-10	2.23E-10	3.22E-10	2.66E-10	2.40E-10	3.00E-10
10.000000	3.03E-10	2.02E-10	3.23E-10	2.97E-10	2.47E-10	3.07E-10	2.98E-10	2.53E-10	3.26E-10