



ORAU TEAM Dose Reconstruction Project for NIOSH

Oak Ridge Associated Universities | Dade Moeller | MJV Technical Services

Page 1 of 15

DOE Review Release 11/26/2013

<p>Document Title: ICRP 116 External Dose Conversion Factors</p>	<p>Document Number: ORAUT-RPRT-0063 Revision: 00 Effective Date: 11/19/2013 Type of Document: Report Supersedes: None</p>
<p>Subject Expert(s): Matthew H. Smith</p>	
<p>Approval: <u>Signature on File</u> Matthew H. Smith, Document Owner</p>	<p>Approval Date: <u>11/04/2013</u></p>
<p>Concurrence: <u>Signature on File</u> John M. Byrne, Objective 1 Manager</p>	<p>Concurrence Date: <u>11/06/2013</u></p>
<p>Concurrence: <u>Signature on File</u> Edward F. Maher, Objective 3 Manager</p>	<p>Concurrence Date: <u>11/05/2013</u></p>
<p>Concurrence: <u>Vickie S. Short Signature on File for</u> Kate Kimpan, Project Director</p>	<p>Concurrence Date: <u>11/04/2013</u></p>
<p>Approval: <u>Signature on File</u> James W. Neton, Associate Director for Science</p>	<p>Approval Date: <u>11/19/2013</u></p>

New
 Total Rewrite
 Revision
 Page Change

FOR DOCUMENTS MARKED AS A TOTAL REWRITE, REVISION, OR PAGE CHANGE, REPLACE THE PRIOR REVISION AND DISCARD / DESTROY ALL COPIES OF THE PRIOR REVISION.

PUBLICATION RECORD

EFFECTIVE DATE	REVISION NUMBER	DESCRIPTION
11/19/2013	00	New document initiated for evaluation of ICRP 116 external dose conversion factors. Incorporates formal internal and NIOSH review comments. Training required: As determined by the Objective Manager. Initiated by Matthew H. Smith.

TABLE OF CONTENTS

<u>SECTION</u>	<u>TITLE</u>	<u>PAGE</u>
Acronyms and Abbreviations		4
1.0	Introduction	5
2.0	Background.....	5
3.0	Comparison Results.....	6
4.0	Summary and Conclusions	7
References		8
ATTACHMENT A,	COMPARISON OF ICRP 74 AND ICRP 116 AP DCF VALUES FOR THE <30 keV, 30–250 keV, AND >250 keV PHOTON ENERGY RANGES AND THE 0.1–2 MeV NEUTRON ENERGY RANGE	9

LIST OF TABLES

<u>TABLE</u>	<u>TITLE</u>	<u>PAGE</u>
2-1	Organs listed in ICRP Report 74, ICRP Report 74 Surrogate Organs Recommended by OTIB-0005 and Organs listed in ICRP Report 116	6
3-1	ICRP 116 organs with greatest increased POC when compared to ICRP 74 data	7
3-2	ICRP 116 organs with decreased POC when compared to ICRP 74 data	7

ACRONYMS AND ABBREVIATIONS

AP	Anterior-Posterior
DCF	Dose Conversion Factor
ET	Extrathoracic
ICRP	International Commission on Radiological Protection
IREP	Interactive RadioEpidemiological Program
KERMA	Kinetic Energy Released in Material
keV	kiloelectron-volt, 1,000 electron-volts
MeV	megaelectron-volt, 1 million electron-volts
mrem	millirem
NIOSH	National Institute for Occupational Safety and Health
POC	Probability Of Causation
RBM	Red Bone Marrow
SI	Small Intestine
yr	year

1.0 INTRODUCTION

Section 4 of the *External Dose Reconstruction Implementation Guide* describes the methodology used to convert individual dosimetry data to organ dose values for use with probability of causation calculations (NIOSH 2007). For a given organ of interest, the methodology makes use of data from ICRP Report 74, which provides organ dose conversion coefficients to convert from free-air KERMA to absorbed dose for photons and, for neutrons, organ dose conversion factors (DCF) per neutron fluence (ICRP 1996). In 2010, the data of ICRP Report 74 was updated in ICRP Report 116. The newer report makes use of updated phantom models for reference male and reference female (ICRP 2009). These models are more realistic because they are based on computed tomography data for real people (ICRP 2009). Given the availability of new data for both male and female subjects, a comparison was performed to determine the change in dose conversion factors published in Attachment A of the *Implementation Guide* and the effect on calculation of probability of causation.

2.0 BACKGROUND

The methods for calculating exposure (R) and $H_p(10)$ photon DCFs are given in sections 4.1.1.1 and 4.1.1.2 of the *External Dose Reconstruction Implementation Guide*, respectively (NIOSH 2007). Exposure DCFs were calculated by dividing the free-air kerma values in ICRP 116 by the exposure to free-air kerma (K_a) conversion factors given in Table 4.1 of the *Implementation Guide* (NIOSH 2007). $H_p(10)$ DCFs was calculated by dividing the free-air kerma values in ICRP 116 by the $H_p(10)$ conversion coefficients given in ICRP 74, Table A.24 (ICRP 1996, NIOSH 2007). The method for calculating neutron $H_{p, \text{slab}}(10)$ DCFs is given in section 4.2.2.1 of the *Implementation Guide* (NIOSH 2007). This section outlines the use of neutron fluence conversion factors from ICRP 74 – located in Table A.41 – and the use of the radiation weighting factor (w_R) – as described in the glossary of ICRP 74 - for converting $H_{p, \text{slab}}(10)$ neutron values to organ dose.

Finally, since the DCFs for photons and neutrons are defined as continuous functions of energy, the dose conversion simplification method – as described in section 4.1.3 of the *Implementation Guide* – was used with the ICRP 116 data. The area under the DCF energy curve for a given radiation type and energy range was evaluated and divided by the range (i.e. 30–250 keV) to determine the average DCF for that energy range (NIOSH 2007). The methods used previously with ICRP 74 data were used with the updated ICRP 116 data in order to maintain consistency when comparing the results.

This comparison encompassed developing DCF values for all of the organ data available in ICRP 116 for both male and female genders. In addition to the 17 organs defined in ICRP 74/IG-001, 14 organs that are “new” in ICRP 116 were analyzed—a total of 31 organs/tissues. These organs are listed in Table 2-1. Surrogates for those organs not directly listed in ICRP 74 are given in Table 2-1 based on the guidance from ORAUT-OTIB-0005, *Internal Dosimetry Organ, External Dosimetry Organ, and IREP Model Selection by ICD-9 Code* (ORAUT 2012).

Attachment A of this report lists the percentage differences from the current AP geometry DCF values for the <30 keV, 30–250 keV, and >250 keV photon energy ranges as well as the 0.1–2 MeV neutron energy range. In addition, the percent difference in IREP-Probability of Causation (POC) values when using the ICRP 116 data versus the ICRP 74 data is given for situations where the greatest differences in the DCF values were identified. Probability of causation is a measure of how likely it is that a cancer was “at least as likely as not” caused by exposure to ionizing radiation. The POC results at the upper 99th percentile confidence interval reported by IREP are the values that were compared. IREP calculations were performed assuming a 10 year work period starting at age 35 with a latency period of 3 years assumed for leukemia, 7 years for thyroid, and 10 years for all other cancers. A photon dose of 500 mrem/yr was partitioned as follows: 100 mrem <30 keV, 300 mrem 30–250 keV, and 100 mrem >250 keV. A neutron dose of 250 mrem was assigned to the 0.1–2 MeV

Table 2-1. Organs listed in ICRP Report 74, ICRP Report 74 Surrogate Organs Recommended by OTIB-0005, and Organs listed in ICRP Report 116.

ICRP 74 Organs	ICRP 74 Surrogate Organs Recommended by OTIB-0005	ICRP 116 Organs
	Remainder	Adrenals
Bone surface	Bone surface	Bone surface
	Remainder	Brain
Breast (female)	Breast	Breast
Colon	Colon	Colon
Esophagus	Esophagus	Esophagus
	Remainder	Extrathoracic (ET) region
Eye	Eye lens	Eye lens
	Liver	Gall bladder
Gonads (male – testes)	Gonads (male – testes)	Gonads (male – testes)
Gonads (female – ovaries)	Gonads (female – ovaries)	Gonads (female – ovaries)
	Thymus	Heart
	Liver	Kidneys
Liver	Liver	Liver
Lungs	Lungs	Lungs
	Thymus	Lymphatic nodes
	Remainder	Muscle
	Remainder	Oral mucosa
	Stomach	Pancreas
	Bladder	Prostate (male)
Red bone marrow	Red bone marrow	Red bone marrow
Remainder	Remainder tissues	Remainder tissues
	Remainder	Salivary glands
Skin	Skin	Skin
	Stomach	Small intestine
	Stomach	Spleen
Stomach	Stomach	Stomach
Thymus	Thymus	Thymus
Thyroid	Thyroid	Thyroid
Bladder	Urinary bladder	Urinary bladder
Uterus	Uterus (female)	Uterus (female)

energy range. In each instance, the IREP calculations were performed 30 times – each with a setting of 10,000 iterations – and the average resulting POC values were used for the comparisons.

3.0 **COMPARISON RESULTS**

Mixed results were observed when comparing DCF values between ICRP 74 and ICRP 116 data. When overall effect on POC was considered, 19 organs had lower POC while 12 had increased values. In many cases, DCF values may have increased for a certain type of radiation/energy range, but the effect on overall POC was still negative when other radiation types/energy ranges were considered. Variation in actual DCF values was greatest (sometimes in excess of 100%) for the <30 keV photon category. Tables 3-1 and 3-2 list organs that showed an increase and decrease in POC, respectively. Gender associated with the organs is noted as “M” for male and “F” for females. In the instances where an increased POC was found for a given organ type, the gender with the greatest increase was identified in Table 3-1, followed by the increase seen in the POC value. The organ showing the greatest increase was red bone marrow. This increase (when compared to ICRP 74) is also discussed in ICRP 116. The prime rationale for the differences in DCF values is the use of updated phantom models. This is stated best in the text of Report 116 (ICRP 2010):

“Overall, the main differences between organ dose conversion coefficients in ICRP Publication 74 (ICRP 1996) and those of the present report can be attributed to the more realistic anatomy represented by the reference phantoms from ICRP Publication 110 (ICRP 2009).”

Table 3-1. ICRP 116 organs with greatest increased POC when compared to ICRP 74 data.

Breast (M) (+1.15%)	Red bone marrow (F) (+8.11%)
Colon (F) (+1.59%)	Remainder tissues (F) (+0.99%)
Esophagus (F) (+4.37%)	Salivary glands (M) (+0.09%)
Extrathoracic (ET) region (M) (+0.6%)	Skin (F) (+0.98%)
Muscle (F) (+0.96%)	Thyroid (F) (+0.35%)
Oral mucosa (F) (+0.76%)	Urinary Bladder (F) (+2.37%)

Table 3-2. ICRP 116 organs with decreased POC^a when compared to ICRP 74 data.

Adrenals (M, F)	Pancreas (M, F)
Bone surface (M, F) (-1.65%)	Prostate (M)
Brain (M, F)	Salivary Glands (F)
Breast (F)	Small intestine (M, F)
Eye lens (M, F) (-8.99%)	Spleen (M, F)
Gall bladder (M, F)	Stomach (M, F)
Heart (M, F)	Testes (M, F)
Kidneys (M, F)	Thymus (M, F) (-0.05%)
Liver (M, F) (-0.14%)	Thyroid (M)
Lungs (M, F) (-0.03%)	Urinary Bladder (M)
Lymphatic nodes (M, F) (-1.6%)	Uterus (F) (0%)
Ovaries (F)	

a. Reduced POC values are given for organs where some DCF values increased while other DCF values decreased. For organs where DCF values decreased for all categories, a direct IREP POC value comparison was not performed since the POC would be reduced due to the overall reduction in assigned organ dose.

It should also be noted that several organs in ICRP 116 have no analogy in ICRP 74 data; therefore, the comparison was made against ICRP 74 organs defined in OTIB-0005 *Internal Dosimetry Organ, External Dosimetry Organ, and IREP Model Selection by ICD-9 Code* (ORAUT 2012).

4.0 **SUMMARY AND CONCLUSIONS**

Significant variations in DCF and POC values were observed when comparing results based on ICRP 116 to ICRP 74 data. A detailed summary of these comparisons is shown in Attachment A of this report. While many of the results show a decrease in DCF and POC values, enough organ comparisons showed an increase in POC values such that a further programmatic review of implementing the newer DCF values of ICRP 116 is warranted. Also, the information in ICRP 116 may have an impact on the estimation of occupational medical dose (note that in addition to AP, PA, ISO, and ROT geometries, RLAT (right-lateral) and LLAT (left-lateral) air kerma values are available in ICRP 116). Use of the newer DCF values will result in a more accurate estimation of external dose based on gender and organ selection, which is more comprehensive in ICRP 116.

REFERENCES

- ICRP (International Commission on Radiological Protection), 1996, *Conversion Coefficients for Use in Radiological Protection Against External Radiation*, Publication 74, Pergamon Press, Oxford, England.
- ICRP (International Commission on Radiological Protection), 2009, *Adult Reference Computational Phantoms*, Publication 110, Ann ICRP 39(2).
- ICRP (International Commission on Radiological Protection), 2010, *Conversion Coefficients for Radiological Protection Quantities for External Radiation Exposures*, Publication 116, Elsevier Press, Philadelphia, Pennsylvania.
- NIOSH (National Institute for Occupational Safety and Health), 2007, *External Dose Reconstruction Implementation Guideline, Rev. 3*, DCAS-IG-001, Division of Compensation Analysis and Support, Cincinnati, Ohio.
- ORAUT (Oak Ridge Associated Universities Team), 2012, *Internal Dosimetry Organ, External Dosimetry Organ, and IREP Model Selection by ICD-9 Code*, ORAUT-OTIB-0005, Rev. 05, Oak Ridge, Tennessee, December 20.

ATTACHMENT A
COMPARISON OF ICRP 74 AND ICRP 116 AP DCF VALUES FOR THE <30 keV, 30–250 keV,
AND >250 keV PHOTON ENERGY RANGES AND THE 0.1–2 MeV NEUTRON ENERGY RANGE

Page 1 of 7

	74	116	% Diff	74	116	% Diff	74	116	% Diff	74	116	% Diff
	Male AP	Male AP		Male AP	Male AP		Female AP	Female AP		Female AP	Female AP	
	Hp(10)	Hp(10)		R	R		Hp(10)	Hp(10)		R	R	
Adrenals												
<30 keV	0.078	0.002	-97%	0.071	0.002	-97%	0.078	0.010	-87%	0.071	0.012	-82%
30–250 keV	0.621	0.347	-44%	0.879	0.490	-44%	0.621	0.400	-36%	0.879	0.565	-36%
>250 keV	0.815	0.678	-17%	0.787	0.653	-17%	0.815	0.717	-12%	0.787	0.691	-12%
0.1–2 MeV	0.525	0.193	-63%				0.525	0.329	-37%			
Bladder												
<30 keV	0.166	0.080	-52%	0.175	0.087	-50%	0.166	0.396	138%	0.175	0.330	88%
30–250 keV	0.873	0.808	-8%	1.244	1.151	-7%	0.873	0.928	6%	1.244	1.316	6%
>250 keV	0.913	0.907	-1%	0.883	0.876	-1%	0.913	0.935	2%	0.883	0.904	2%
0.1–2 MeV	0.796	0.697	-12%				0.796	0.974	22%			
IREP							16.86%	19.23%				
Bone Surf												
<30 keV	0.215	0.090	-58%	0.209	0.111	-47%	0.215	0.106	-50%	0.209	0.120	-43%
30–250 keV	0.850	0.692	-19%	1.229	0.986	-20%	0.850	0.735	-14%	1.229	1.047	-15%
>250 keV	0.792	0.841	6%	0.764	0.813	6%	0.792	0.854	8%	0.764	0.819	7%
0.1–2 MeV	0.436	0.548	26%				0.436	0.561	29%			
IREP							16.32%	14.67%				
Brain												
<30 keV	0.078	0.010	-87%	0.071	0.011	-84%	0.078	0.011	-85%	0.071	0.013	-82%
30–250 keV	0.621	0.407	-35%	0.879	0.573	-35%	0.621	0.421	-32%	0.879	0.594	-32%
>250 keV	0.815	0.768	-6%	0.787	0.740	-6%	0.815	0.777	-5%	0.787	0.748	-5%
0.1–2 MeV	0.525	0.336	-36%				0.525	0.377	-28%			
Breast												
<30 keV	0.873	1.173	34%	0.561	0.572	2%	0.873	0.888	2%	0.561	0.491	-12%
30–250 keV	0.894	0.875	-2%	1.266	1.232	-3%	0.894	0.870	-3%	1.266	1.226	-3%
>250 keV	0.966	0.756	-22%	0.930	0.736	-21%	0.966	0.821	-15%	0.930	0.798	-14%
0.1–2 MeV	1.145	1.450	27%				1.145	1.351	18%			
IREP	15.39%	16.54%										

ATTACHMENT A
COMPARISON OF ICRP 74 AND ICRP 116 AP DCF VALUES FOR THE <30 keV, 30–250 keV,
AND >250 keV PHOTON ENERGY RANGES AND THE 0.1–2 MeV NEUTRON ENERGY RANGE

Page 2 of 7

	74	116	% Diff	74	116	% Diff	74	116	% Diff	74	116	% Diff
	Male AP	Male AP		Male AP	Male AP		Female AP	Female AP		Female AP	Female AP	
	Hp(10)	Hp(10)		R	R		Hp(10)	Hp(10)		R	R	
Colon												
<30 keV	0.060	0.121	102%	0.075	0.131	76%	0.060	0.189	214%	0.075	0.202	170%
30–250 keV	0.747	0.745	0%	1.060	1.059	0%	0.747	0.825	10%	1.060	1.167	10%
>250 keV	0.874	0.876	0%	0.844	0.846	0%	0.874	0.907	4%	0.844	0.878	4%
0.1–2 MeV	0.490	0.637	30%				0.490	0.738	51%			
IREP							8.54%	10.13%				
Esophagus												
<30 keV	0.010	0.073	603%	0.014	0.078	448%	0.010	0.068	556%	0.014	0.080	457%
30–250 keV	0.486	0.639	32%	0.688	0.906	32%	0.486	0.760	56%	0.688	1.084	58%
>250 keV	0.772	0.859	11%	0.745	0.829	11%	0.772	0.884	15%	0.745	0.854	15%
0.1–2 MeV	0.412	0.540	31%				0.412	0.587	42%			
IREP							9.79%	14.16%				
ET												
<30 keV	0.078	0.276	256%	0.071	0.212	200%	0.078	0.148	91%	0.071	0.126	79%
30–250 keV	0.621	0.672	8%	0.879	0.949	8%	0.621	0.592	-5%	0.879	0.834	-5%
>250 keV	0.815	0.860	5%	0.787	0.831	6%	0.815	0.838	3%	0.787	0.808	3%
0.1–2 MeV	0.525	0.764	45%				0.525	0.614	17%			
IREP	2.57%	3.17%										
Eye Lens												
<30 keV	3.624	0.148	-96%	0.936	0.126	-87%	3.624	0.148	-96%	0.936	0.126	-87%
30–250 keV	0.879	0.592	-33%	1.236	0.834	-33%	0.879	0.592	-33%	1.236	0.834	-33%
>250 keV	0.908	0.838	-8%	0.880	0.808	-8%	0.908	0.838	-8%	0.880	0.808	-8%
0.1–2 MeV	0.525	1.285	145%									
IREP	16.51%	7.52%										
Gall Bladder												
<30 keV	0.095	0.032	-66%	0.106	0.041	-62%	0.095	0.049	-48%	0.106	0.065	-39%
30–250 keV	0.748	0.644	-14%	1.064	0.915	-14%	0.748	0.698	-7%	1.064	0.991	-7%
>250 keV	0.886	0.818	-8%	0.845	0.790	-7%	0.886	0.860	-3%	0.845	0.831	-2%
0.1–2MeV	0.641	0.487	-24%				0.641	0.554	-14%			

ATTACHMENT A
COMPARISON OF ICRP 74 AND ICRP 116 AP DCF VALUES FOR THE <30 keV, 30–250 keV,
AND >250 keV PHOTON ENERGY RANGES AND THE 0.1–2 MeV NEUTRON ENERGY RANGE

Page 3 of 7

	74	116	% Diff	74	116	% Diff	74	116	% Diff	74	116	% Diff
	Male AP	Male AP		Male AP	Male AP		Female AP	Female AP		Female AP	Female AP	
	Hp(10)	Hp(10)		R	R		Hp(10)	Hp(10)		R	R	
Heart Wall												
<30 keV	0.273	0.101	-63%	0.288	0.113	-61%	0.273	0.123	-55%	0.288	0.138	-52%
30–250 keV	0.991	0.748	-25%	1.408	1.062	-25%	0.991	0.767	-23%	1.408	1.091	-22%
>250 keV	0.922	0.874	-5%	0.892	0.844	-5%	0.922	0.890	-3%	0.892	0.860	-4%
0.1–2MeV	1.086	0.641	-41%				1.086	0.683	-37%			
Kidney												
<30 keV	0.095	0.007	-93%	0.106	0.006	-94%	0.095	0.023	-76%	0.106	0.031	-71%
30–250 keV	0.748	0.402	-46%	1.064	0.570	-46%	0.748	0.543	-27%	1.064	0.770	-28%
>250 keV	0.886	0.698	-21%	0.845	0.672	-21%	0.886	0.790	-11%	0.845	0.761	-10%
0.1–2 MeV	0.641	0.222	-65%				0.641	0.350	-45%			
Liver												
<30 keV	0.095	0.062	-35%	0.106	0.075	-30%	0.095	0.108	13%	0.106	0.126	18%
30–250 keV	0.748	0.655	-12%	1.064	0.931	-12%	0.748	0.738	-1%	1.064	1.047	-2%
>250 keV	0.886	0.829	-6%	0.845	0.800	-5%	0.886	0.872	-2%	0.845	0.843	0%
0.1–2 MeV	0.641	0.518	-19%				0.641	0.631	-1%			
IREP							19.65%	19.51%				
Lung												
<30 keV	0.082	0.100	22%	0.100	0.111	10%	0.082	0.091	11%	0.100	0.097	-4%
30–250 keV	0.695	0.681	-2%	0.986	0.965	-2%	0.695	0.662	-5%	0.986	0.938	-5%
>250 keV	0.870	0.875	1%	0.842	0.845	0%	0.870	0.865	-1%	0.842	0.832	-1%
0.1–2 MeV	0.557	0.591	6%				0.557	0.537	-4%			
IREP	12.67%	12.64%										
Lymphoid												
<30 keV	0.273	0.285	4%	0.288	0.211	-27%	0.273	0.222	-19%	0.288	0.199	-31%
30–250 keV	0.991	0.739	-25%	1.408	1.046	-26%	0.991	0.751	-24%	1.408	1.063	-24%
>250 keV	0.922	0.862	-6%	0.892	0.833	-7%	0.922	0.881	-5%	0.892	0.851	-5%
0.1–2 MeV	1.086	0.696	-36%				1.086	0.699	-36%			
IREP	6.69%	5.09%										

ATTACHMENT A
COMPARISON OF ICRP 74 AND ICRP 116 AP DCF VALUES FOR THE <30 keV, 30–250 keV,
AND >250 keV PHOTON ENERGY RANGES AND THE 0.1–2 MeV NEUTRON ENERGY RANGE

Page 4 of 7

Muscle	74	116	% Diff									
	Male AP	Male AP		Male AP	Male AP		Female AP	Female AP		Female AP	Female AP	
	Hp(10)	Hp(10)		R	R		Hp(10)	Hp(10)		R	R	
<30 keV	0.078	0.202	161%	0.071	0.174	146%	0.078	0.164	111%	0.071	0.152	115%
30–250 keV	0.621	0.632	2%	0.879	0.892	2%	0.621	0.644	4%	0.879	0.911	4%
>250 keV	0.815	0.844	3%	0.787	0.814	4%	0.815	0.854	5%	0.787	0.825	5%
0.1–2MeV	0.525	0.612	16%				0.525	0.596	13%			
IREP							12.02%	12.98%				
Oral Mucosa	74	116	% Diff									
	Male AP	Male AP		Male AP	Male AP		Female AP	Female AP		Female AP	Female AP	
	Hp(10)	Hp(10)		R	R		Hp(10)	Hp(10)		R	R	
<30 keV	0.078	0.073	-5%	0.071	0.062	-13%	0.078	0.140	80%	0.071	0.112	59%
30–250 keV	0.621	0.583	-6%	0.879	0.825	-6%	0.621	0.643	3%	0.879	0.909	3%
>250 keV	0.815	0.855	5%	0.787	0.825	5%	0.815	0.878	8%	0.787	0.848	8%
0.1–2 MeV	0.525	0.675	29%				0.525	0.694	32%			
IREP							6.02%	6.78%				
Ovaries	74	116	% Diff	74	116	% Diff						
	Female AP	Female AP		Female AP	Female AP							
	Hp(10)	Hp(10)		R	R							
<30 keV	0.034	0.022	-35%	0.047	0.026	-44%						
30–250 keV	0.672	0.628	-7%	0.955	0.889	-7%						
>250 keV	0.849	0.833	-2%	0.819	0.804	-2%						
0.1–2 MeV	0.424	0.424	0%									
Pancreas	74	116	% Diff									
	Male AP	Male AP		Male AP	Male AP		Female AP	Female AP		Female AP	Female AP	
	Hp(10)	Hp(10)		R	R		Hp(10)	Hp(10)		R	R	
<30 keV	0.167	0.032	-81%	0.182	0.039	-78%	0.167	0.072	-57%	0.182	0.091	-50%
30–250 keV	0.881	0.652	-26%	1.251	0.927	-26%	0.881	0.762	-14%	1.251	1.083	-13%
>250 keV	0.915	0.828	-9%	0.885	0.800	-10%	0.915	0.884	-3%	0.885	0.854	-3%
0.1–2 MeV	0.824	0.441	-46%				0.824	0.617	-25%			
Prostate	74	116	% Diff	74	116	% Diff						
	Male AP	Male AP		Male AP	Male AP							
	Hp(10)	Hp(10)		R	R							
<30 keV	0.166	0.016	-90%	0.175	0.018	-90%						
30–250 keV	0.873	0.652	-25%	1.244	0.924	-26%						
>250 keV	0.913	0.844	-8%	0.883	0.814	-8%						
0.1–2 MeV	0.796	0.510	-36%									

ATTACHMENT A
COMPARISON OF ICRP 74 AND ICRP 116 AP DCF VALUES FOR THE <30 keV, 30–250 keV,
AND >250 keV PHOTON ENERGY RANGES AND THE 0.1–2 MeV NEUTRON ENERGY RANGE

Page 5 of 7

RBM	74	116	% Diff	74	116	% Diff	74	116	% Diff	74	116	% Diff
	Male AP	Male AP		Male AP	Male AP		Female AP	Female AP		Female AP	Female AP	
	Hp(10)	Hp(10)		R	R		Hp(10)	Hp(10)		R	R	
<30 keV	0.030	0.078	158%	0.025	0.085	244%	0.030	0.087	187%	0.025	0.098	299%
30–250 keV	0.479	0.642	34%	0.626	0.914	46%	0.479	0.690	44%	0.626	0.984	57%
>250 keV	0.746	0.809	8%	0.720	0.780	8%	0.746	0.826	11%	0.720	0.798	11%
0.1–2 MeV	0.361	0.445	23%				0.361	0.471	31%			
IREP							41.30%	49.41%				
Remainder	74	116	% Diff	74	116	% Diff	74	116	% Diff	74	116	% Diff
	Male AP	Male AP		Male AP	Male AP		Female AP	Female AP		Female AP	Female AP	
	Hp(10)	Hp(10)		R	R		Hp(10)	Hp(10)		R	R	
<30 keV	0.078	0.113	46%	0.071	0.100	42%	0.078	0.110	41%	0.071	0.111	58%
30–250 keV	0.621	0.632	2%	0.879	0.893	2%	0.621	0.669	8%	0.879	0.947	8%
>250 keV	0.815	0.826	1%	0.787	0.797	1%	0.815	0.851	4%	0.787	0.822	4%
0.1–2 MeV	0.525	0.556	6%				0.525	0.596	13%			
IREP							12.02%	13.01%				
Salivary Glands	74	116	% Diff	74	116	% Diff	74	116	% Diff	74	116	% Diff
	Male AP	Male AP		Male AP	Male AP		Female AP	Female AP		Female AP	Female AP	
	Hp(10)	Hp(10)		R	R		Hp(10)	Hp(10)		R	R	
<30 keV	0.078	0.146	88%	0.071	0.142	101%	0.078	0.072	-6%	0.071	0.081	15%
30–250 keV	0.621	0.605	-3%	0.879	0.852	-3%	0.621	0.561	-10%	0.879	0.791	-10%
>250 keV	0.815	0.881	8%	0.787	0.851	8%	0.815	0.858	5%	0.787	0.829	5%
0.1–2 MeV	0.525	0.567	8%				0.525	0.511	-3%			
IREP	2.87%	2.96%										
SI Wall	74	116	% Diff	74	116	% Diff	74	116	% Diff	74	116	% Diff
	Male AP	Male AP		Male AP	Male AP		Female AP	Female AP		Female AP	Female AP	
	Hp(10)	Hp(10)		R	R		Hp(10)	Hp(10)		R	R	
<30 keV	0.167	0.118	-30%	0.182	0.131	-28%	0.167	0.129	-23%	0.182	0.144	-21%
30–250 keV	0.881	0.767	-13%	1.251	1.090	-13%	0.881	0.785	-11%	1.251	1.116	-11%
>250 keV	0.915	0.880	-4%	0.885	0.850	-4%	0.915	0.891	-3%	0.885	0.861	-3%
0.1–2 MeV	0.824	0.628	-24%				0.824	0.685	-17%			

ATTACHMENT A
COMPARISON OF ICRP 74 AND ICRP 116 AP DCF VALUES FOR THE <30 keV, 30–250 keV,
AND >250 keV PHOTON ENERGY RANGES AND THE 0.1–2 MeV NEUTRON ENERGY RANGE

Page 6 of 7

	74	116	% Diff	74	116	% Diff	74	116	% Diff	74	116	% Diff
	Male AP	Male AP		Male AP	Male AP		Female AP	Female AP		Female AP	Female AP	
	Hp(10)	Hp(10)		R	R		Hp(10)	Hp(10)		R	R	
Skin												
<30 keV	1.706	1.858	9%	0.504	0.514	2%	1.706	2.099	23%	0.504	0.540	7%
30–250 keV	0.633	0.652	3%	0.892	0.921	3%	0.633	0.664	5%	0.892	0.938	5%
>250 keV	0.867	0.584	-33%	0.835	0.566	-32%	0.867	0.570	-34%	0.835	0.554	-34%
0.1–2 MeV	0.853	0.848	-1%				0.853	0.868	2%			
IREP							11.62%	12.60%				
Spleen												
<30 keV	0.167	0.011	-93%	0.182	0.014	-92%	0.167	0.024	-86%	0.182	0.030	-83%
30–250 keV	0.881	0.419	-52%	1.251	0.594	-52%	0.881	0.498	-43%	1.251	0.707	-43%
>250 keV	0.915	0.720	-21%	0.885	0.694	-22%	0.915	0.775	-15%	0.885	0.745	-16%
0.1–2 MeV	0.824	0.243	-71%				0.824	0.316	-62%			
Stomach												
<30 keV	0.167	0.102	-39%	0.182	0.121	-34%	0.167	0.150	-10%	0.182	0.167	-8%
30–250 keV	0.881	0.759	-14%	1.251	1.078	-14%	0.881	0.783	-11%	1.251	1.115	-11%
>250 keV	0.915	0.876	-4%	0.885	0.846	-4%	0.915	0.894	-2%	0.885	0.864	-2%
0.1–2 MeV	0.824	0.634	-23%				0.824	0.722	-12%			
Testes												
<30 keV	0.978	0.516	-47%	0.622	0.404	-35%						
30–250 keV	1.011	0.942	-7%	1.434	1.341	-7%						
>250 keV	0.973	0.904	-7%	0.941	0.873	-7%						
0.1–2MeV	1.307	1.045	-20%									
Thymus												
<30 keV	0.273	0.314	15%	0.288	0.287	0%	0.273	0.307	12%	0.288	0.293	2%
30–250 keV	0.991	0.930	-6%	1.408	1.317	-6%	0.991	0.931	-6%	1.408	1.317	-6%
>250 keV	0.922	0.972	5%	0.892	0.941	6%	0.922	0.959	4%	0.892	0.930	4%
0.1–2 MeV	1.086	1.114	3%				1.086	1.090	0%			
IREP	4.33%	4.28%										

ATTACHMENT A
COMPARISON OF ICRP 74 AND ICRP 116 AP DCF VALUES FOR THE <30 keV, 30–250 keV,
AND >250 keV PHOTON ENERGY RANGES AND THE 0.1–2 MeV NEUTRON ENERGY RANGE

Page 7 of 7

	74	116	% Diff	74	116	% Diff	74	116	% Diff	74	116	% Diff
	Male AP	Male AP		Male AP	Male AP		Female AP	Female AP		Female AP	Female AP	
	Hp(10)	Hp(10)		R	R		Hp(10)	Hp(10)		R	R	
Thyroid												
<30 keV	0.538	0.469	-13%	0.473	0.418	-12%	0.538	0.566	5%	0.473	0.487	3%
30–250 keV	1.017	1.005	-1%	1.440	1.430	-1%	1.017	1.015	0%	1.440	1.451	1%
>250 keV	1.003	0.969	-3%	0.972	0.938	-3%	1.003	0.973	-3%	0.972	0.941	-3%
0.1–2 MeV	1.086	1.137	5%				1.086	1.187	9%			
IREP							25.30%	25.65%				
Uterus												
	74	116	% Diff	74	116	% Diff						
	Female AP	Female AP		Female AP	Female AP		Female AP	Female AP				
	Hp(10)	Hp(10)		R	R							
<30 keV	0.044	0.032	-29%	0.061	0.042	-31%						
30–250 keV	0.711	0.664	-7%	1.011	0.941	-7%						
>250 keV	0.812	0.851	5%	0.786	0.822	5%						
0.1–2 MeV	0.424	0.513	21%									
IREP	0.25%	0.25%										