

Chapter 7

THERMOLUMINESCENCE DOSIMETRY FOR GAMMA RAYS

Part A. Thermoluminescence Measurements

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Introduction

Gamma dose, rather than neutron dose, is of primary importance in the dosimetry of the atomic-bomb survivors in Hiroshima and Nagasaki, as this is the predominant component of total dose to survivors. As an example, Figure 1 shows a smoothed curve through values based on the calculated shielded kerma at the locations of individual survivors, with neutron and gamma-ray kerma simply added together to produce a total shielded kerma (i.e., with no multiplication of the neutron kerma by a weighting factor), and neutron kerma expressed as a fraction of the total. In Hiroshima, the fraction attributable to neutrons does not exceed about 7% at the most proximal survivor distances for either DS02 or DS86, which have almost identical fractions due to neutrons, and the fractions decrease rapidly with increasing distance. In Nagasaki the fraction is less than 2% at the most proximal distances, and the fraction for DS02 is distinctly less than for DS86.

This chapter concerns the *in situ* measurements of gamma dose in bomb-exposed materials from Hiroshima and Nagasaki that have utilized the technique of thermoluminescence dosimetry. Thermoluminescence (TL) is a property of a material that causes it to emit light as a result of being excited by heat. Measurement of TL is a standard method in radiation protection dosimetry, using prepared materials with special properties, but the retrospective application of the method in atomic-bomb dosimetry is a different matter. In the early 1960s, thermoluminescence had been widely studied as a physical phenomenon in natural materials, had been used for dating limestone sediments, and was being developed in archaeology for the purpose of estimating the age of fired ceramic artifacts (Ichikawa et al. 1966). Japanese scientists ingeniously developed and applied similar techniques to estimate dose in environmental materials from exposures due to the atomic bombs many years earlier. This was the first technique developed for estimating dose-related

quantities in environmental materials of Hiroshima and Nagasaki, beginning in the early 1960s (Higashimura et al. 1963), and remains the bulwark of the existing physical measurements that directly validate the survivor dosimetry. Dose reconstructions were performed mainly using measurements of ceramic materials such as bricks and tiles that were present as parts of buildings and other structures (e.g., brick fences) in the cities of Hiroshima and Nagasaki at the times of the bombings (Ichikawa et al. 1966; Hashizume et al. 1967a,b).

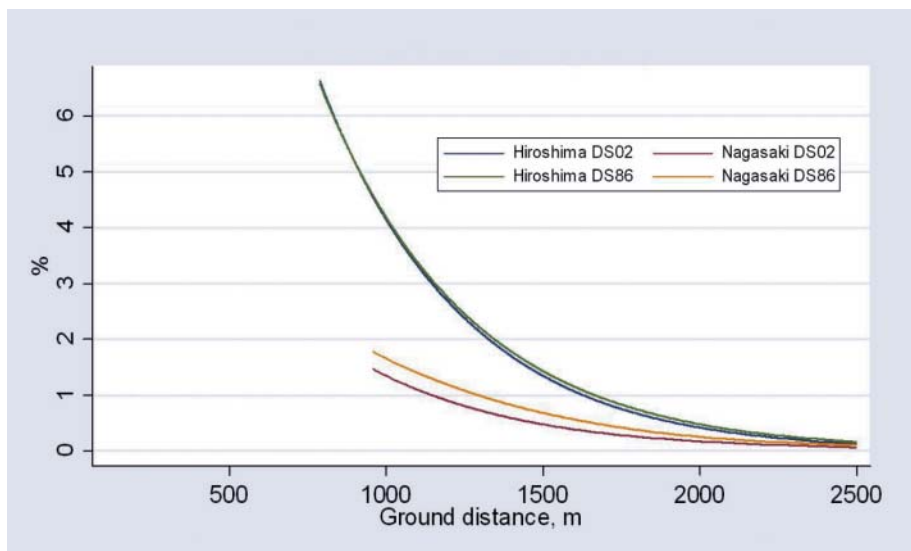


Figure 1. Fraction of total shielded kerma from neutrons at individual survivor locations.

In the 1980s, considerable progress was made in the branch of solid-state dosimetry, including TL, and in computer sciences and technology. In the TL measurement techniques of ceramic materials normally used for archaeological dating, the dose range of currently developed methods extends from tens of mGy to 100 Gy. Over the years investigators in the particular field of atomic-bomb dosimetry have refined their techniques by improving equipment, devising new methods using different electron “traps” at particular energy levels and corresponding temperatures, and purifying materials to separate the portions with the most reliable radiation-induced signal. As techniques for atomic-bomb dosimetry improved and measurements became more sensitive and accurate, investigators sought to extend their measurements to further and further distances from the hypocenters, where the largest numbers of survivors were located. A total of 125 different measurements in Hiroshima and about half that number in Nagasaki were initially included in the analysis for this section, and various others have been made but were not technically suitable for this analysis.

In light of the current situation, this chapter has several major purposes. One is to summarize the work that has been done since the publication of the DS86 Final Report (Maruyama et al. 1987), which was a major milestone in the application of TL to atomic-bomb dosimetry. Another

is to undertake an uncertainty analysis, particularly in light of concerns that have been raised by the Committee on Dosimetry for the Radiation Effects Research Foundation of the U.S. National Research Council (2001) in the wake of suggestions in recent years, albeit more directly related to neutron dosimetry, that doses in Hiroshima were inaccurately calculated by DS86. Finally, another major objective is to evaluate the total body of measurement data now available in relation to the new dosimetry system that was developed as part of DS02.

Specification of Dose

Because measurers have typically reported doses in units of dose to *tissue*, we have retained that convention in this section. In Part B of this chapter, as explained below, comparisons of calculated to measured values are typically done in units of dose to *quartz*. We have tried to indicate in all cases (e.g., by footnotes to tables) which specification applies to particular values. We have consistently used a conversion factor of 0.916 Gy to quartz per unit Gy to tissue, as discussed further below.

Measurements Since DS86

Two Japanese groups have continued to make measurements since DS86. The group at Nara University of Education and Hiroshima University (NUE-HU) has made measurements exclusively in Hiroshima, using the quartz inclusion technique. All of the newer measurements by this group have previously been reported as described below, and are included below in the summary tables with DS86 and earlier measurements. The group at the Japan National Institute of Radiological Sciences (JNIRS) has also continued to make measurements in both cities, using the high temperature technique for doses above about 3 Gy and the pre-dose technique for all other measurements. Based on this rule, the pre-dose technique has been used almost exclusively in post-DS86 measurements by the JNIRS group due to the longer distances at which they have been made. The newest JNIRS measurements will be published shortly in a separate paper. As they have not been reported elsewhere, they are described here and listed in separate tables in the next section. All of the post-DS86 measurements by both groups are included in Table 1 and the related analysis of this section regarding background, and in the comprehensive tables of Part B of this chapter.

Thermoluminescence Dosimetry for Gamma Rays

Table 1.a. Background doses and dose rates for all measurements: DS86 Final Report (Maruyama et al. 1987): Hiroshima

Lab	Place and sample	Sample ID#	RERF list No.	Sample type	Beta (mGy/y)	±	Gamma (mGy/y)	±	Total (mGy/y)	±	Age (y)	±	Total bkg dose (Gy)	±	Dose to:	Re-reported dist (m)
DUR	H.U.F.S. (Hiro. Univ.)	UHFSFT02	3-35	Tile	2.1	0.2	1.15	1	3.25	1.02	52	2	0.160	0.059	quartz	1454
DUR	H.U.F.S. (Hiro. Univ.)	UHFSFT02	3-35	Tile	2.1	0.2	1.15	1	3.25	1.02	52	2	0.160	0.059	quartz	1454
JNIRS	Naka Telephone Office	3	1-01	Tile											tissue	507
JNIRS	Naka Telephone Office	2	1-19	Tile											tissue	523
JNIRS	Sanin Bank		12-02	Tile											tissue	621
JNIRS	Chugoku Elec Co	1	2-01	Tile											tissue	665
JNIRS	Chugoku Elec Co	2	2-03	Tile											tissue	691
JNIRS	H.U.F.S. (Hiro. Univ.)	7	3-07	Tile	2.65	.32	1.25	0.04	3.9	0.32	52	2	0.203	0.020	tissue	1366
JNIRS	H.U.F.S. (Hiro. Univ.)	10	3-10	Tile	2.65	.32	1.25	0.04	3.9	0.32	52	2	0.203	0.020	tissue	1366
JNIRS	H.U.F.S. (Hiro. Univ.)	1	3-28	Tile	2.65	.32	1.25	0.04	3.9	0.32	52	2	0.203	0.020	tissue	1393
JNIRS	H.U.F.S. (Hiro. Univ.)	1	3-29	Tile	2.65	.32	1.25	0.04	3.9	0.32	52	2	0.203	0.020	tissue	1416
JNIRS	H.U.F.S. (Hiro. Univ.)	IV	3-31	Tile	2.65	.32	1.25	0.04	3.9	0.32	52	2	0.203	0.020	tissue	1420
JNIRS	H.U.F.S. (Hiro. Univ.)	14	3-14	Tile	2.65	.32	1.25	0.04	3.9	0.32	52	2	0.203	0.020	tissue	1428
JNIRS	Red Cross Hospital		5-01	Tile	2.75	.36	1.21	0.07	3.96	0.37	44	2	0.174	0.021	tissue	1433
JNIRS	H.U.F.S. (Hiro. Univ.)	1	3-01	Tile	2.65	.32	1.25	0.04	3.9	0.32	52	2	0.203	0.020	tissue	1443
JNIRS	Ryomatsu sho		11-04	Brick	1.91	.38	1.2	0.08	3.11	0.39	73	2	0.227	0.034	tissue	3387
JNIRS	H.U.F.S. (Hiro. Univ.)	R		Tile	2.65	.32	1.25	0.04	3.9	0.32	52	2	0.203	0.020	tissue	1450
JNIRS	Chokin-Kyoku			Tile	2.96	.45	1.25	0.09	4.21	0.46	47	2	0.198	0.027	tissue	1607
NUE	Naka Telephone Office	203-3	1-04	Tile											Roentgen	523
NUE	Naka Telephone Office	204-2	1-04	Tile											Roentgen	523
NUE	Naka Telephone Office	204-3	1-04	Tile											Roentgen	523
NUE	Chugoku Electric Co.	3-1-3	2-03	Wall tile	2.64	10	1.1	10	3.74	14.14	55		0.206		tissue	692
NUE	Chugoku Electric Co.	3-1-3	2-03	Wall tile	2.64	10	1.1	10	3.74	14.14	55		0.206		tissue	692
NUE	Chugoku Electric Co.	3-2-2	2-03	Wall tile	2.81	10	1.1	10	3.91	14.14	55		0.215		tissue	692
NUE	Chugoku Electric Co.	3-2-2	2-03	Wall tile	2.81	10	1.1	10	3.91	14.14	55		0.215		tissue	692
NUE	Chugoku Electric Co.	3-2-3	2-03	Wall tile	2.96	10	1.1	10	4.06	14.14	55		0.223		Roentgen	692
NUE	H.U.P.S. (Hiro. Univ.)	H-1	4-08	tile, railing	2.49	0.007	0.82	0.04	3.31	0.04	45	2	0.149	0.008	Roentgen	1271
NUE	HUFS. "T" Bldg	H1	4-08	tile, railing, roof	2.49	0.007	0.82	0.04	3.31	0.04	45	2	0.149	0.008	tissue	1271
NUE	H.U.P.S. (Hiro. Univ.)	H-3	4-09	tile, railing	2.49	0.007	0.82	0.04	3.31	0.04	45	2	0.149	0.008	Roentgen	1298
NUE	H.U.P.S. (Hiro. Univ.)	H-2	4-07	Tile, eaves	2.49	0.007	0.82	0.04	3.31	0.04	45	2	0.149	0.008	air (R*)	1282
NUE	H.U.P.S. (Hiro. Univ.)	H-4	4-01	Tile, eaves	2.49	0.007	0.82	0.04	3.31	0.04	45	2	0.149	0.008	air (R*)	1316

Thermoluminescence Dosimetry for Gamma Rays

Table 1.a. Continued

Lab	Place and sample	Sample ID#	RERF list No.	Sample type	Beta (mGy/y)	±	Gamma (mGy/y)	±	Total (mGy/y)	±	Age (y)	±	Total bkg dose (Gy)	±	Dose to:	Re-reported dist (m)
NUE	H.U.P.S. (Hiro. Univ.)	H-5	4-03	tile, railing	2.49	0.007	0.82	0.04	3.31	0.04	45	2	0.149	0.008	air (R*)	1336
NUE	H.U.F.S. (Hiro. Univ.)	H-6-1	3-20	tile, floor	2.71	0.007	0.88	0.03	3.59	0.03	52	2	0.187	0.009	air (R*)	1388
NUE	H.U.F.S. (Hiro. Univ.)	H-6-2	3-20	tile, floor	2.71	0.007	0.88	0.03	3.59	0.03	52	2	0.187	0.009	air (R*)	1388
NUE	H.U.F.S. (Hiro. Univ.)	H-6-3	3-20	tile, floor	2.71	0.007	0.88	0.03	3.59	0.03	52	2	0.187	0.009	air (R*)	1388
NUE	H.U.F.S. (Hiro. Univ.)	H-7	3-36	tile, railing	2.71	0.007	0.88	0.03	3.59	0.03	52	2	0.187	0.009	air (R*)	1393
NUE	H.U.F.S. (Hiro. Univ.)	H-8	3-18	tile, floor	2.71	0.007	0.88	0.03	3.59	0.03	52	2	0.187	0.009	air (R*)	1422
NUE	H.U.F.S. (Hiro. Univ.)	H-9	3-17	tile, floor	2.71	0.007	0.88	0.03	3.59	0.03	52	2	0.187	0.009	air (R*)	1428
NUE	H.U.F.S. (Hiro. Univ.)	H-10-1	3-15	tile, floor	2.71	0.007	0.88	0.03	3.59	0.03	52	2	0.187	0.009	air (R*)	1451
NUE	H.U.F.S. (Hiro. Univ.)	H-10-2	3-15	tile, floor	2.71	0.007	0.88	0.03	3.59	0.03	52	2	0.187	0.009	air (R*)	1451
NUE	H.U.F.S. (Hiro. Univ.)	H-10-3	3-15	tile, floor	2.71	0.007	0.88	0.03	3.59	0.03	52	2	0.187	0.009	air (R*)	1451
NUE	H.U.F.S. (Hiro. Univ.)	H-10-4	3-15	tile, floor	2.71	0.007	0.88	0.03	3.59	0.03	52	2	0.187	0.009	air (R*)	1451
NUE	H.U.F.S. (Hiro. Univ.)	H-11	3-16	tile, floor	2.71	0.007	0.88	0.03	3.59	0.03	52	2	0.187	0.009	air (R*)	1461
NUE	Japanese house (Nobori-cho)			Oni-gawara											air (R*)	1131
NUE	HUFS "I" Bldg	H-5B		tile, railing, roof	2.37	0.007	0.78	0.04	3.15	0.04	45	2	0.142	0.800	tissue	1298
NUE	HUFS "E" Bldg	HP1		tile, wall	2.57	0.007	0.84	0.03	3.41	0.03	52	2	0.177	0.009	tissue	1378
NUE	HUFS "E" Bldg	HP2		tile, railing, roof	2.57	0.007	0.84	0.03	3.41	0.03	52	2	0.177	0.009	tissue	1388
NUE	HUFS "E" Bldg	HP3		tile, wall	2.57	0.007	0.84	0.03	3.41	0.03	52	2	0.177	0.009	tissue	1388
NUE	Red Cross Hospital	HP4		tile, floor of roof	3.29	1.06	1.16	10	4.45	10.06	45		0.200		tissue	1451
NUE	Chokin-kyoku (Postal Savings)			Roof tile	3.23	.32	0.82	0.04	4.05	0.32	42	2	0.162	0.017	air (R*)	1597
NUE	Meisen-ji "onigawara" top	Me-1		Roof ornament	1.1	10	1.4	10	2.5	14.14	71		0.178		tissue	1909
NUE	Meisen-ji "onigawara" bottom	Me-2		Roof ornament	1.1	10	1.4	10	2.5	14.14	71		0.178		tissue	1909
NUE	H.U.F.E.	HP5		tile, wall	3.12	10	0.96	10	4.08	14.14	55		0.053		tissue	2041
NUE	Hiramoto "onigawara" bottom	Hr-1		Roof ornament	2.4	10	1	10	3.4	14.14	48		0.163		tissue	2053
NUE	Kirihara	Ki-1		Roof tile	2.5	10	0.7	10	3.2	14.14	66		0.211		tissue	2453
NUE	Kirihara	Ki-2		Roof tile	1.1	10	1.3	10	2.4	14.14	66		0.158		tissue	2453
NUE	Kirihara	Ki-3		Roof tile	1.7	10	1.3	10	3	14.14	66		0.198		tissue	2453
NUE	Kirihara	Ki-4		Roof tile	1.7	10	1.3	10	3	14.14	66		0.198		tissue	2453
OXF	H.U.F.S. (Hiro. Univ.)	UHFSFT03	3-35	Tile	2.1	0.21	1.15	1	3.25	1.02	52	2	0.169	0.063	quartz	1454
OXF	H.U.F.S. (Hiro. Univ.)	UHFSFT03	3-35	Tile	2.1	0.21	1.15	1	3.25	1.02	52	2	0.169	0.063	quartz	1454

Thermoluminescence Dosimetry for Gamma Rays

Table 1.a. Continued

Lab	Place and sample	Sample ID#	RERF list No.	Sample type	Beta (mGy/y)	±	Gamma (mGy/y)	±	Total (mGy/y)	±	Age (y)	±	Total bkg dose (Gy)	±	Dose to:	Reported dist (m)
OXF	H.U.F.S. (Hiro. Univ.)	UHFSFT03	3-35	Tile	2.3	0.46	1.15	1	3.45	1.10	52	2	0.179	0.076	quartz	1454
U of U	H.U.F.S. (Hiro. Univ.)	UHFSO3	3-23	Tile	3.08	0.15	1.15	0.1	4.23	0.18	52	2	0.196	0.014	quartz	1386
U of U	H.U.F.S. (Hiro. Univ.)	UHFSO2	3-22	Tile	3.08	0.15	1.15	0.1	4.23	0.18	52	2	0.196	0.014	quartz	1426
U of U	H.U.F.S. (Hiro. Univ.)	UHFSO1	3-21	Tile	10	10	10	10	20	14.14			0.000		quartz	1433
U of U	H.U.F.S. (Hiro. Univ.)	UHFSO5	3-25	Tile	3.08	0.15	1.15	0.1	4.23	0.18	52	2	0.196	0.014	quartz	1451
U of U	H.U.F.S. (Hiro. Univ.)	UHFSFT02	3-35	Tile	2	0.2	1.15	1	3.15	1.02	52	2	0.148	0.057	quartz	1454
U of U	H.U.F.S. (Hiro. Univ.)	UHFSFT03	3-35	Tile	2	0.2	1.15	1	3.15	1.02	52	2	0.148	0.057	quartz	1454
U of U	H.U.F.S. (Hiro. Univ.)	UHFSO4	3-24	Tile	3.08	0.15	1.15	0.1	4.23	0.18	52	2	0.196	0.014	quartz	1389
U of U	H.U.F.S. (Hiro. Univ.)	UHFSO7	3-27	Tile	3.08	0.15	1.15	0.1	4.23	0.18	52	2	0.196	0.014	quartz	1455
U of U	H.U.F.S. (Hiro. Univ.)	UHFSO6	3-26	Tile	3.08	0.15	1.15	0.1	4.23	0.18	52	2	0.196	0.014	quartz	1430

Note: R* = Roentgen; DUR = Durham University, UK; JNIRS = Japan National Institute of Radiological Sciences; NUE = Nara University of Education, Japan; OXF = Oxford University, UK; U of U = University of Utah, USA.

Table 1.a. Background doses and dose rates for all measurements: DS86 Final Report (Maruyama et al. 1987): Nagasaki

Lab	Place and sample	Sample ID#	RERF list No.	Sample type	Beta (mGy/y)	±	Gamma (mGy/y)	±	Total (mGy/y)	±	Age (y)	±	Total bkg dose (Gy)	±	Dose to:	Reported dist (m)
DUR	Ieno wall	NAIEO5	N-2	Brick											quartz	1427
DUR	Ieno wall	NAIEO5	N-2	Brick											quartz	1427
DUR	Ieno wall	NAIEO5	N-2	Brick											quartz	1427
DUR	Ieno wall	NAIEO5	N-2	Brick											quartz	1427
DUR	Ieno wall	NAIEO5	N-2	Brick											quartz	1427
DUR	Ieno wall	NAIEO5	N-2	Brick											quartz	1427
JNIRS	Urakami		N4	Brick											tissue	459
JNIRS	Sakamoto		N-6	Brick	2.18	0.28	1.09	0.3	3.27	0.41	50	5	0.164	0.033	tissue	1079
JNIRS	Zenza		N-7	Brick	1.82	0.22	1.05	0.06	2.87	0.23	60	3	0.172	0.019	tissue	1437
JNIRS	Ieno	A	N-2	Brick	2.18	0.28	1.09	0.3	3.27	0.41	50	5	0.164	0.033	tissue	1427
JNIRS	Ieno	B	N-2	Brick	2.18	0.28	1.09	0.3	3.27	0.41	50	5	0.164	0.033	tissue	1427
JNIRS	Ieno	C	N-2	Brick	2.18	0.28	1.09	0.3	3.27	0.41	50	5	0.164	0.033	tissue	1437
JNIRS	Inasa	A	N-3	Brick	2.95	0.38	1.1	0.04	4.05	0.38	80	15	0.324	0.069	tissue	2026
JNIRS	Inasa	B	N-3	Brick	2.95	0.38	1.1	0.04	4.05	0.38	80	15	0.324	0.069	tissue	2026
JNIRS	Inasa	C	N-3	Brick	2.95	0.38	1.1	0.04	4.05	0.38	80	15	0.324	0.069	tissue	2026
JNIRS	Inasa	D	N-3	Brick	2.95	0.38	1.1	0.04	4.05	0.38	80	15	0.324	0.069	tissue	2036
JNIRS	Inasa	E	N-3	Brick	2.95	0.38	1.1	0.04	4.05	0.38	80	15	0.324	0.069	tissue	2036
JNIRS	Inasa	F	N-3	Brick	2.95	0.38	1.1	0.04	4.05	0.38	80	15	0.324	0.069	tissue	2036
JNIRS	Chikugo		N-8	Brick	2.62	0.47	1.11	0.05	3.73	0.47	80	12	0.224	0.055	tissue	2369
NUE	Brazier (Shiroyama 1s)		N-17	brazier											tissue	731
NUE	Ieno roof tile	N-177	N-18	Roof tile											air (R*)	1600
NUE	Ceramic shard		N-38	shard											air (R*)	1075
NUE	Ieno wall	A	N-2	Brick											air (R*)	1427
NUE	Ieno wall	B	N-2	Brick											air (R*)	1427
NUE	Ieno wall	C	N-2	Brick											air (R*)	1427
OXF	Ieno wall	NAIEO5	N-2	Brick											quartz	1427
OXF	Ieno wall	NAIEO5	N-2	Brick											quartz	1427
OXF	Ieno wall	NAIEO5	N-2	Brick											quartz	1427
U of U	Ieno wall	NAIEO6	N-2	Brick											quartz	1427
U of U	Ieno wall	NAIEO6	N-2	Brick											quartz	1427
U of U	Ieno wall	NAIEO6	N-2	Brick											quartz	1427

Thermoluminescence Dosimetry for Gamma Rays

Table 1.b. Background doses and dose rates for all measurements: Ichikawa et al. 1987: Hiroshima

Lab	Place and sample	Sample ID#	RERF list No.	Sample type	Beta (mGy/y)	±	Gamma (mGy/y)	±	Total (mGy/y)	±	Age (y)	±	Total bkg dose (Gy)	±	Dose to:	Reported dist (m)
NUE	HUFS "I"	H1		Tile	2.36	0.07	0.77	0.04	3.13	0.08	45	1	0.140	0.007	tissue (?)	1268
NUE	HUFS "I"	H2		Tile	2.36	0.07	0.77	0.04	3.13	0.08	45	1	0.140	0.007	tissue (?)	1277
NUE	HUFS "I"	H3		Tile	2.36	0.07	0.77	0.04	3.13	0.08	45	1	0.140	0.007	tissue (?)	1295
NUE	HUFS "I"	H4		Tile	2.36	0.07	0.77	0.04	3.13	0.08	45	1	0.140	0.007	tissue (?)	1314
NUE	HUFS "I"	H5		Tile	2.36	0.07	0.77	0.04	3.13	0.08	45	1	0.140	0.007	tissue (?)	1335
NUE	HUFS "E"	H6		Tile	2.58	0.07	0.85	0.04	3.42	0.08	52	1	0.177	0.007	tissue (?)	1387
NUE	HUFS "E"	H7		Tile	2.58	0.07	0.85	0.04	3.42	0.08	52	1	0.177	0.007	tissue (?)	1397
NUE	HUFS "E"	H8		Tile	2.58	0.07	0.85	0.04	3.42	0.08	52	1	0.177	0.007	tissue (?)	1421
NUE	HUFS "E"	H9		Tile	2.58	0.07	0.85	0.04	3.42	0.08	52	1	0.177	0.007	tissue (?)	1426
NUE	HUFS "E"	H10		Tile	2.58	0.07	0.85	0.04	3.42	0.08	52	1	0.177	0.007	tissue (?)	1449
NUE	HUFS "E"	H11		Tile	2.58	0.07	0.85	0.04	3.42	0.08	52	1	0.177	0.007	tissue (?)	1460

Table 1.c. Background doses and dose rates for all measurements: Nagatomo et al. 1988: Hiroshima

Lab	Place and sample	Sample ID#	RERF list No.	Sample type	Beta (mGy/y)	±	Gamma (mGy/y)	±	Total (mGy/y)	±	Age (y)	±	Total bkg dose (Gy)	±	Dose to:	Reported dist (m)
NUE	HUFS "I"	HP1		Tile	2.37	0.07	0.78	0.04	3.15	0.08	45	1	0.142	0.006	tissue (?)	1271
NUE	HUFS "I"	HP2		Tile	2.37	0.07	0.78	0.04	3.15	0.08	45	1	0.142	0.006	tissue (?)	1338
NUE	HUFS "E"	HP3		Tile	2.57	0.07	0.84	0.03	3.41	0.08	52	1	0.177	0.006	tissue (?)	1378
NUE	HUFS "E"	HP4, HP5		Tile	2.57	0.07	0.84	0.03	3.41	0.08	52	1	0.177	0.006	tissue (?)	1388
NUE	Red Cross Hospital	HP6		Tile	3.29	0.07	1.06	0.05	4.35	0.09	45	1	0.196	0.007	tissue (?)	1451
NUE	JEMIC	HP7		Tile	3.44	0.07	0.88	0.04	4.32	0.08	47	1	0.203	0.007	tissue (?)	1793
NUE	HUFE	HP8		Tile	3.12	0.05	0.96	0.05	4.08	0.07	55	1	0.224	0.007	tissue (?)	2051

Table 1.d. Background doses and dose rates for all measurements: Hoshi et al. 1989: Hiroshima

Lab	Place and sample	Sample ID#	RERF list No.	Sample type	Beta (mGy/y)	±	Gamma (mGy/y)	±	Total (mGy/y)	±	Age (y)	±	Total bkg dose (Gy)	±	Dose to:	Reported dist (m)
NUE	Meisen-ji "onigawara" top	A-1		Tile	1.07	0.07	1.40	0.07	2.47	0.10	70.8	1	0.177	0.007	tissue	1909
NUE	Meisen-ji "onigawara" bottom	A-2		Tile	1.07	0.07	1.40	0.07	2.47	0.10	70.8	1	0.177	0.007	tissue	1909
NUE	Hiramoto "Onigawara"	B		Tile	2.36	0.15	1.03	0.11	3.39	0.18	48	1	0.162	0.011	tissue	2053
NUE	HUFE clay wall tile	C-1		Tile	3.13	0.22	0.96	0.07	4.08	0.23	55	1	0.224	0.011	tissue	2054
NUE	HUFE clay wall tile	C-2		Tile	3.13	0.22	0.96	0.07	4.08	0.23	55	1	0.224	0.011	tissue	2054
NUE	HUFE clay wall tile	C-3		Tile	3.13	0.22	0.96	0.07	4.08	0.23	55	1	0.224	0.011	tissue	2054
NUE	Kirihara "Hiragawara"	D-1		Tile	2.47	0.15	0.74	0.22	3.20	0.27	66.3	1	0.210	0.018	tissue	2453
NUE	Kirihara "Hiragawara"	D-2		Tile	1.10	0.07	1.29	0.22	2.39	0.23	66.3	1	0.158	0.015	tissue	2453
NUE	Kirihara "Hiragawara"	D-3		Tile	1.69	0.11	1.29	0.22	2.98	0.25	66.3	1	0.199	0.018	tissue	2453
NUE	Kirihara "Hiragawara"	D-4		Tile	1.69	0.11	1.29	0.22	2.98	0.25	66.3	1	0.199	0.018	tissue	2453