Soil particle size measurements for the calculation of the spread of dusts blown up by the explosion of the Hiroshima atomic bomb

- For radiation dose estimation from neutron activated dusts of soils used in traditional Japanese houses and those of the ground surface -

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Abstract

Radiation doses for the atomic bomb survivors in Hiroshima have been calculated for the direct exposure cases within about 2 km range by dosimetry system 2002 (DS02). In this system beta-ray exposure and internal exposure were not included. At that time such portions of the radiation doses were not considered to be significant for risk estimation. However, there are some discussions that the beta-ray exposure may not have been negligible. According to one of the calculations, skin surface doses due to the neutron activated soil dust come up to a few to several hundreds of mGy (Tanaka et al. 2008). The purpose of this study is to measure particle sizes, since soil particles were activated by neutrons and sometimes fission products were attached. These data will be used to estimate such radiation doses. Using these data, we need to calculate the spread of the dust by the shockwave of the atomic bomb explosion and how it fell down to the atomic bomb survivors. We collected two types of samples such as (1) soil used in walls and roofs in old traditional Japanese houses (in Fukuyama city in Hiroshima prefecture) and (2) ground surface soil samples taken from the depth of 0-1 cm and 1-2 cm in the Hiroshima city area. Particle sizes were measured after using 2 mm mesh sieves. Results of the weight average of the traditional Japanese houses were for soil under roof tiles 23.8 μm and for walls 56.0 μm. Those for the ground surface data from 5 places in Hiroshima city area (0-2 cm thickness) ranged from 40.9 to 105.7 μm.

Introduction

Radiation risks have been mainly obtained from epidemiological study using dosimetry system 2002 (DS02) by the Radiation Effects Research Foundation (RERF) (Ozasa et al. 2012). The risks obtained by RERF have been discussed in the International Commission on Radiological Protection (ICRP) and used to determine their recommendations on radiation risks.

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After this, the recommendations were used by each country to protect radiation workers and the general public. In Japan these risks are used in the "Laws Concerning the Prevention from Radiation Hazards due to Radioisotopes".

Recently Ohtaki et al.(2013) found relatively high risks even in the long-distance area from about 2 km outward, where DS02 dose is less than 80 mGy in Hiroshima. Such effects have not been considered in the risks used in radiation protection. Also, in the direction to the northwest, relatively high risks were obtained where "black rain" fell down soon after the atomic bombing.

Similar analysis was made before by Stram and Mizuno (1989), who found high rates of epilation of scalp hair at relatively long distances more than 2 km. Cullings 2012-13, by the case of epilation of scalp hair, analyzed difference by direction, however no pattern was found for the distribution.

There have been questions in scientific discussions around the world regarding such observations. Sometimes similar human effects such as epilation (Stram and Mizuno, 1989), etc., seem to have appeared in places where calculated external doses were not very high (for example Imanaka et al. 2008). DS02 is used for the evaluation of radiation risks but only by external gamma ray and neutron doses. We are going to consider additional radiations not included in DS02. One is beta ray exposure (Tanaka et al. 2008) from materials adhering to the skin surface. Another is inhalation of activated soil particles. For example, soil dusts in the area were irradiated by neutrons, which induced radioactivity.

To perform such estimation, soil particle size measurements will be necessary to calculate how much and how long soil-derived particulates were spread into the air within a few km ground range. After this, the particles may have been inhaled, and also such particles may have attached to exposed skin surfaces and irradiated the skin externally by gamma rays and beta rays.

In this study, two types of samples were collected. One type was from the old traditional Japanese houses in which soil with straw is used under roofs and walls. In the old Hiroshima city area all buildings except a small number of concrete buildings were such houses. In addition, total amounts of soil used in traditional Japanese houses are obtained in this regard based on Aoyama et al. (2013), for dose calculation. The other type is ground surface soils. We collected ground surface soils from 5 places in the Hiroshima city area.

The spectrum of the particle sizes was measured and the data will be used for the calculation of the spread of the soil-derived dusts in the city area by the severe shock wave of the Hiroshima atomic bomb detonation.

Materials and Methods

Sample collection and preparation

The soils from the traditional Japanese houses were collected. Under the roof tiles they used soil, and walls were made from soil with straw. In the Hiroshima city area almost all houses were this type. Within a 2 km area from the hypocenter, such houses were totally blown down and later burned out. Therefore, at the time of blow-down, a major part of the airborne soil dust may have come from these houses. We took one sample each from a wall and under a roof and measured them. These samples were from Fukuyama city near Hiroshima city.

The other type of soil samples were collected from the 5 places in the Hiroshima city area as listed in Table 1 with the coordinates of the points. They are located in directions between eastward and southward from hypocenter. Sanyo Buntokuden Memorial (sample point No. 1), former-Hiroshima University (2) and Yoshijima park (3) are about 2 km ground range and the other two Shinonome park (4) and Ujina park (5) are about 3.5 km. Sanyo Buntokuden Memorial (1) is located beside Hijiyama mountain where old surface soil from the time of bombing (ATB) was retained to the present day. This was stated by a "Hibakusya" who has been living nearby since ATB. In the case of the old Faculty of Science, Hiroshima University building (2) only one building has been kept after bombing (located now in a newly constructed park), which was exposed ATB. So, soil samples were taken from the two inner courtyard garden surfaces which have been kept since ATB without disturbance. In the Yoshijima park (3) there are many large trees which seem to have been there since before ATB. Samples near those trees were taken. This place may have retained old surfaces. The other 2 places (Shinonome No. 2 park (4) and Ujina No. 1 park (5)) had been graded flat for use as parks, so the surfaces are not old ones. However there are not so many samples obtainable which represent old surface soils, because the Hiroshima city area was totally burnt down and rebuilt. Also, the soil types in Hiroshima city are from granite rocks produced by long weathering. Therefore soil surfaces seem similar everywhere. So these samples were also taken and measured to see differences among places. Dates of the sample collection were on 6 November, 2012 for the three samples; Yoshijima park (3), Shinonome park (4) and Ujina park (5) , on 12 December for the sample Sanyo Buntokuden Memorial (1) and on 26 December for the sample former-Hiroshima University (2). All of these days were fine at the time of sampling.

At each sampling location of the 5 places, 3 – 5 points that seemed undisturbed were selected for sampling using a special scraper. From each sampling point, surface soil samples at 0-1 cm and 1 – 2 cm depth with an area of 10 × 12 cm^2 were taken. Each sample was dried for two days with 80 ºC in oven and weighed. Large particles were removed using 2 mm mesh sieves and the remainder was used for particle size measurements. Before and after drying the sample, the weight was measured. Furthermore, the ratio over 2 mm size soil is also measured.

Particle size measurement

A few grams of the soil samples were taken from each sample and stirred using a ultrasound stirrer for 3 min to measure fully disturbed particle size distribution. About 25 ml of each suspended sediment was used for the particle size distribution measurements (He et al. 1995, Mizugaki et al. 2008), using Shimadzu SALD-3100 (Shimadzu Corp., Kyoto, Japan). The measurements were made 3 times for each sediment. The Shimadzu SALD-3100 has the capacity to handle samples with grain sizes ranging from 0.05 µm to 3000 µm. The particles in the analyzed samples were classified into 51 size ranges from 0.05 to 2000 µm. Results were obtained as spectra of fractions, median values and weight averages.

Results and discussion

Weight averages of the particle size of soil under roof tiles and in walls used for the traditional Japanese houses are shown in Table 2-1. The average of the soil under roof tiles is 23.8 µm and is relatively small compared with that for walls of 56.0 µm. The data for the ground surface are shown in Table 2-2. The values are fluctuating, however there seemed to be no special trend of the differences among these data. The particle sizes of soils from the ground surface are similar to those of wall data but not to soil used under roof tiles.

The ground surface data of the samples No. 4 and 5 were disturbed at the time of maintenance for the use as parks and seem not so different from the other data from areas that have maintained their original surface. This may be due to the soil of the Hiroshima area’s coming from granite rock, so soils have the same origin and have the same characteristics.

The depth difference between 0 – 1 cm and 1 – 2 cm depths are shown in this Table 2-2, however clear differences are not seen from the data. Therefore for the frequency spectrum the two depth data were averaged and are shown in Table A-1 of the Appendix.

In Figure 1 the frequency spectra of the soil samples from the houses are shown. In the case of the roof tile spectrum, the major grain sizes are smaller and different from that of the wall. In the case of Hiroshima, these types of soils were used in all of the wooden Japanese houses, which were totally torn down by the atomic bomb blast within 2 km ground range. So these results will be considered important in the calculation of the spread of soil dust.

Figure 2 shows the particle size spectra compared among 5 places. Bimodal peaks are found in all of the data points at around 0.4 μm and 100 μm. All of the spectra show this similar pattern. This is similar to that of the house wall shown in Figure 1. Only the spectrum of the soil under roof tiles has a different pattern.

Obtained soil size data in this study will be useful for the calculation of the spread of the soil particles in air. After this, calculation of the neutron activation will be performed. Then exposed radiation doses will be calculated for the people immediately after bombing who escaped from this area and also those who entered into the area to find and to save people. They passed through this area under this soil dust and were possibly exposed. This calculation will also be useful to understand possible additional irradiation to DS02 (Ohtaki 2013); i.e., how the movement of activated soil by the blast may have affected the total gamma ray exposure rate from activated soil as a function of time and location. Also this exposure will be useful to understand exposed people internally and externally in Chernobyl, Semipalatinsk, Fukushima and so on.

Table 1 Summary of collection places of the ground surface soil samples.

Sample point No.	Name	Notation	Latitude	Longitude	Dry weight (g)		Water* content (%)
					>2mm	<2mm	
1	Sanyo Buntokuden Memorial	Hinano mountain	34.386417	132.471233	139.4	567.7	12.5
		Nearby park on the hill	34.385833	132.471483	143.4	629.7	18.7
		Beside main building	34.386333	132.471767	371.1	605.7	19.9
2	Old Hiroshima University Faculty of Science building	Inner court north	34.382307	132.458679	331.1	835.2	14.6
		Inner court south	34.382044	132.458867	213.3	1056.2	17.1
3	Yoshijima park		34.377942	132.450569	0.0	2011.8	14.3
4	Shinonome No. 2 park		34.380886	132.490245	124.4	2544.2	8.4
5	Ujina No. 1 park		34.366917	132.471094	143.1	2066.6	10.1

*Obtained from the reduction of the weight after dry up. See text.

Table 2-1 Results of soil used in the traditional Japanese houses.

Name	Notation	Weighted average of the particle sizes (μm, condition dry)
Soil used in a traditional Japanese house	Used under roof tiles	23.8
	Used as the wall	56.0

Table 2-2 Results of the averages of the ground soil surface samples.

Sample point No.	Name	Notation	Weighted average of the particle size (μm)	
			Depth 0–1 cm	Depth 1–2 cm
1	Sanyo Buntokuden Memorial	Hinano mountain	93.0	77.8
		Near by park on the hill	86.6	90.7
		Beside main building	81.6	57.2
2	Old Hiroshima university faculty of science building	Inner court north	57.2	177.4
		Inner court south	105.7	40.9
3	Yoshijima park		55.8	46.2
4	Shinonome No. 2 park		62.5	57.2
5	Ujina No. 1 park		56.1	54.0

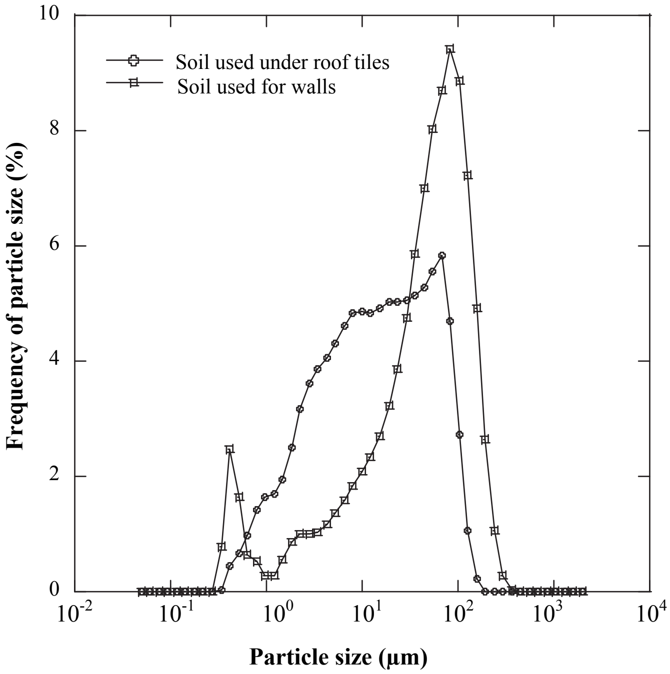

Figure 1 Frequency spectra of the particle sizes for the soil samples from traditional Japanese houses. The soils used under roof tiles (○) and for walls (□) are shown.

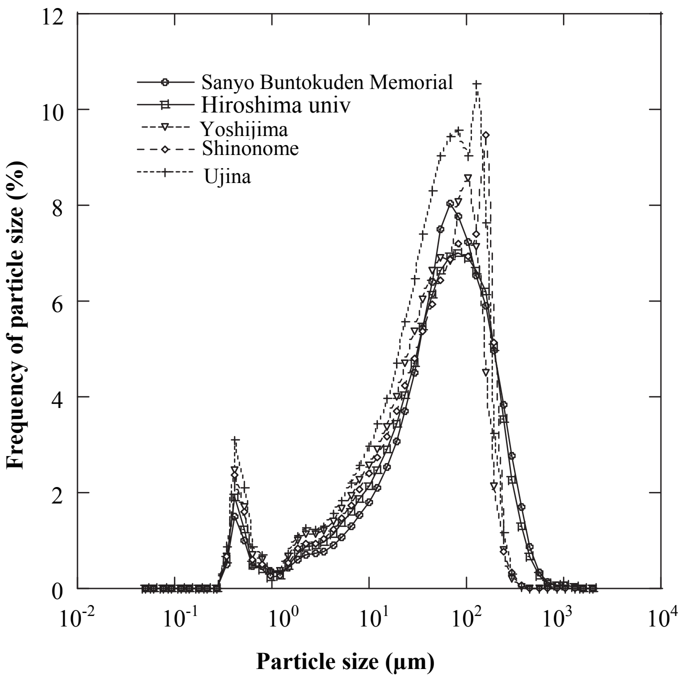

Figure 2 Frequency of the particle sizes for the Sanyo Buntokuden Memorial (○), Old Hiroshima university faculty of science building(□), Yoshijima park(▽), Shinonome No. 2 park(◇), and Ujina No. 1 park(＋) ground surface soil samples. Data points of each place are averages of 0 – 1 cm and 1 – 2 cm depth, and in the case of Sanyo Buntokuden Memorial and Hiroshima University all sampling points are averaged and plotted to simplify.

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Appendix

Table A-1 Data table of the particle size frequency (%) for all of the measurements. All frequency data are weight averages of 0-1 cm and 1-2 cm depth sample data.

No	Particle size (μm)	House material		Ground surface soil							
				Sanyo Buntokuden Memorial			Hiroshima University		Yoshijima park	Shinonome No.2 park	Ujina No.1 park
		Roof	Walls	Hinano	Near park hill	Main building	North	South			
		Frequency (%)									
1	2000.00	0.000	0.000	0.005	0.002	0.015	0.000	0.012	0.000	0.000	0.000
2	1618.04	0.000	0.000	0.025	0.001	0.014	0.000	0.036	0.000	0.000	0.000
3	1309.02	0.000	0.000	0.076	0.000	0.008	0.000	0.080	0.000	0.000	0.000
4	1059.03	0.000	0.000	0.155	0.000	0.003	0.000	0.124	0.000	0.000	0.000
5	856.77	0.000	0.000	0.237	0.002	0.003	0.000	0.150	0.000	0.000	0.000
6	693.15	0.000	0.000	0.324	0.055	0.048	0.000	0.233	0.000	0.000	0.000
7	560.77	0.000	0.000	0.536	0.284	0.224	0.000	0.554	0.000	0.000	0.000
8	453.67	0.000	0.000	1.028	0.887	0.646	0.016	1.308	0.000	0.002	0.000
9	367.03	0.000	0.036	1.844	1.952	1.333	0.155	2.455	0.029	0.062	0.043
10	296.93	0.000	0.272	2.842	3.327	2.165	0.741	3.769	0.205	0.325	0.295
11	240.23	0.000	1.059	3.798	4.731	3.025	2.059	4.996	0.786	0.763	1.173
12	194.35	0.003	2.643	5.040	5.945	3.887	4.144	5.939	2.147	5.146	3.226
13	157.23	0.235	4.915	6.054	6.845	4.787	5.878	6.500	4.517	9.459	7.649
14	127.20	1.065	7.218	6.514	7.395	5.692	6.534	6.746	7.142	7.406	10.530
15	102.91	2.725	8.872	7.534	7.669	6.492	6.994	6.810	8.553	6.941	9.047
16	83.26	4.708	9.429	8.374	7.908	7.062	7.258	6.746	8.071	7.187	9.559
17	67.36	5.827	8.697	8.816	8.013	7.269	7.337	6.516	6.850	6.861	9.451
18	54.49	5.551	8.026	8.185	7.259	7.047	7.177	6.096	6.916	6.446	9.049
19	44.09	5.274	7.012	6.550	6.111	6.500	6.733	5.526	6.633	5.943	8.314
20	35.67	5.143	5.851	5.416	5.100	5.784	6.044	4.859	6.043	5.364	7.389
21	28.85	5.044	4.740	4.308	4.137	5.035	5.250	4.176	5.374	4.789	6.454
22	23.34	5.022	3.862	3.426	3.345	4.379	4.513	3.564	4.686	4.242	5.559
23	18.89	5.032	3.221	2.741	2.711	3.794	3.861	3.026	3.998	3.691	4.709
24	15.28	4.929	2.706	2.187	2.179	3.200	3.255	2.531	3.375	3.176	3.983
25	12.36	4.827	2.328	1.782	1.769	2.707	2.781	2.132	2.891	2.744	3.421
26	10.00	4.861	2.079	1.516	1.484	2.368	2.458	1.844	2.558	2.393	2.980
27	8.09	4.828	1.845	1.304	1.254	2.065	2.164	1.595	2.267	2.070	2.581
28	6.55	4.607	1.588	1.098	1.038	1.740	1.848	1.356	1.946	1.748	2.187

Table A-1 Continued

29	5.30	4.320	1.363	0.917	0.858	1.448	1.560	1.153	1.658	1.472	1.851
30	4.28	4.057	1.172	0.764	0.701	1.214	1.313	0.976	1.408	1.229	1.558
31	3.47	3.853	1.026	0.653	0.575	1.056	1.111	0.834	1.200	1.019	1.309
32	2.80	3.617	0.990	0.619	0.548	0.991	1.003	0.779	1.125	0.932	1.225
33	2.27	3.165	1.000	0.606	0.588	0.939	0.953	0.772	1.133	0.941	1.256
34	1.84	2.500	0.860	0.519	0.541	0.788	0.802	0.669	0.990	0.832	1.117
35	1.49	1.940	0.547	0.390	0.361	0.594	0.519	0.439	0.656	0.546	0.731
36	1.20	1.708	0.280	0.327	0.195	0.496	0.271	0.233	0.367	0.282	0.380
37	0.97	1.634	0.272	0.354	0.201	0.526	0.238	0.211	0.347	0.258	0.361
38	0.79	1.421	0.531	0.423	0.393	0.616	0.431	0.386	0.599	0.494	0.693
39	0.64	0.976	0.654	0.388	0.490	0.562	0.520	0.470	0.712	0.607	0.857
40	0.52	0.661	1.646	0.773	1.130	1.100	1.331	1.144	1.706	1.596	2.112
41	0.42	0.432	2.486	1.162	1.593	1.712	2.065	1.714	2.454	2.375	3.088
42	0.34	0.029	0.776	0.396	0.425	0.660	0.688	0.539	0.657	0.663	0.869
43	0.27	0.004	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000