May 12, 2011
Ministry of Education, Culture, Sports, Science and Technology

Calculation Results and Basis regarding Internal Exposure Studied in Summarizing the "Tentative Approach"

Cooperation of the National Institute of Radiological Sciences was obtained, and calculations performed as follows.
External exposure was sought from the air dose rate.
Internal exposure was sought using the following steps. (Used data from soil survey performed on April 14 by Ministry of Education, Culture, Sports, Science and Technology)

- A certain percentage of radioactive substances settled in the soil whirl up into the air (resuspension).
- Coefficients provided by IAEA and NCRP are used for percentage of resuspension.
- Estimates the quantity of resuspended radioactive substances inhaled by respiration (Uses respiration rate and time on site corresponding to age).
- Considers oral ingestion due to mistakenly entering mouth.
- Considers radioactive substances which invade via wounds.
- Estimates absorbed dose (Sv) of radioactive substance quantity (Bq) taken into the body (Uses dose conversion coefficients determined by ICRP).

In case of Koriyama Kaoru Elementary School (dose on school field in 200 school days)
External exposure: 1.5mSv Internal exposure: 0.038mSv Total: 1.538mSv
Percentage of total dose which is from internal exposure dose: 0.038/1.538 = 2.5%

No.	School name	Contribution ratio of internal exposure (%)
3	Kaoru Elementary School, Koriyama	2.5
21	Onami Elementary School, Fukushima	1.6
22	Oguni Elementary School, Date	2.3
27	Seishin Saniku Preschool	2.9
28	Saniku Kindergarten	1.0
29	Tominari Elementary School, Date	1.7
32	Oyama Elementary School, Fukushima	2.4
35	Fukushima Second Junior High School	0.5
36	Fukushima University attached Kindergarten	1.2
37	Fukushima University attached junior high school	0.6
38	Fukushima Seikei Junior High School	0.7
41	Fukushima Third Elementary School	1.8
49	Watari Junior High School, Fukushima	0.9
	13 schools listed above which have at least 3.8μSv/h	Average 1.5%
	Highest values, including other kindergartens and schools	4.1
	Lowest value	0.5
	Average	1.9

Conditions for Assessing Exposure Dose due to Use of School Field

■ Calculation Conditions

- Assess the external exposure and internal exposure from time on the school field, then calculate the contribution of internal exposure.
- Assess external, inhaled, oral and wound exposure from school field contamination.
- Assess from April 14, 2011 to April 14, 2012.
- Time spent on school field is as follows (based on conduct survey of infants, children and students).
  - Kindergarten: 220 kindergarten days; time spent on school field/day: 2 hours
  - Elementary school: 200 school days; time spent on school field/day: 2 hours
  - Junior high school: 200 school days; time spent on school field/day: 4 hours
- For external, inhaled, oral and wound doses, perform “Assessment ignoring decay” and

"Assessment considering decay."

- Ratios of airborne nuclides are assumed to be the same as ratios of nuclides in soil.
- Nuclides subject to assessment: Cs-134, Cs-137, Cs-136, I-131, Te-132, I-132
- soil density is assumed to be 1300 kg/m^3.
- For inhaled exposure, only assess from dust which comes from the school field.
- There is no raw data on Cs-136 soil radioactive concentration, so Cs-136 concentration is estimated from ratios of Cs-137 and Cs-136 in J-Village soil measured by the National Institute of Radiological Sciences (Cs-136/Cs-137 = approximately 0.1. This calculation uses 0.1.).
- For the effective dose conversion coefficients used in internal exposure assessment, values corresponding to each exposure route are used, cited from literature in the table below.

Cited Literature for Effective Dose Conversion Coefficients

Exposure type	**Literature**	**Note**
Inhaled exposure	NCRP-R-129, 1999	Airborne aerosol AMD is from 2 to 6μm
	ICRP	1μm default in public
Oral exposure	ICRP	
Injection exposure (by injury)	IMBA using ICRP model	

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Established this time	**Conversion coefficient used**	**Size and type of particles used**
Inhaled exposure	ICRP 1998 CDROM (ICRP72), NCRP-R-129, 1999	The particle system is 5μm. Its type is the safe side.
Oral exposure	ICRP 1998 CDROM (ICRP72)	
Exposure by injection (injury)	IMBA using ICRP model	

Values of Effective Dose Conversion Coefficients Used (Sv/Bq)

Nuclide	Age	Cs-134	C-137 (Ba137m)	Cs-136	I-131	I-132	Te-132
Inhale	1 year	3.20E-08	4.20E-08	1.00E-08	8.60E-08	1.20E-09	2.00E-08
Inhale	Kindergarten (age 5)	2.30E-08	3.70E-08	6.50E-09	5.00E-08	6.10E-10	1.10E-08
Inhale	Elementary school student (age 10)	1.60E-08	2.60E-08	4.50E-09	2.50E-08	4.20E-10	5.40E-09
Inhale	Junior & senior high school student (age 15)	1.60E-08	2.80E-08	4.30E-09	1.70E-08	2.90E-10	3.80E-09
Inhale	Adult	1.30E-08	2.40E-08	3.10E-09	1.10E-08	2.00E-10	2.80E-09
Oral	1 year	1.60E-08	1.20E-08	9.50E-09	1.80E-07	2.40E-09	3.00E-08
Oral	Kindergarten (age 5)	1.30E-08	9.60E-09	6.10E-09	1.00E-07	1.30E-09	1.60E-08
Oral	Elementary school student (age 10)	1.40E-08	1.00E-08	4.40E-09	5.20E-08	6.20E-10	8.30E-09
Oral	Junior & senior high school student (age 15)	1.90E-08	1.30E-08	3.40E-09	3.40E-08	4.10E-10	5.30E-09
Oral	Adult	1.90E-08	1.30E-08	3.00E-09	2.20E-08	2.90E-10	3.80E-09
Wound (injection)	Adult	1.93E-08	1.35E-08	3.02E-09	2.20E-08	2.75E-10	1.37E-09
Note	Inhaled type	S	S	S	F	F	Age 15, adult: M, otherwise F
		The safest side of each nuclide type was used.					

■ External Exposure

(Calculation Equation)

Effective dose (Sv) = Air dose rate (SV/s) × contribution of nuclide × time on site (s) × decay correction (if correcting)　(1)

Use Equation (1) to find the dose for each nuclide, then total them.

(Parameter Conditions)

• Air Dose Rate

Actual measured values on school fields (assessed from air dose rates at 50cm height in elementary schools and kindergartens, 1m height in junior high schools)

Uses 1cm dose equivalents which are survey meter reading values (raw actual measured values) as effective doses on the safe side.

Conversion of air kerma K and 1cm dose equivalent H are assumed to be equal at each energy. Dose contribution ratio of air kerma = Dose contribution ratio of 1cm dose equivalent.

With energy in the range 0.3MeV to 0.8MeV, H/K is in the range 1.3 to 1.2. E/K of infants is at most approximately 1.2 times in all energy ranges (irradiation conditions: irradiation from ground surface radiation sources). Safe side if H (1cm dose equivalent) is used in effective dose.

• Contribution of nuclides

Assume that all nuclides in soil are at the top surface, seek each nuclide's air dose rate from semi-unlimited level surfaces, and calculate the contribution of air dose rate of each nuclide.

■ Exposure due to Respiration Ingestion

(Calculation Equation)

Effective dose (Sv) = surface contamination density (Bq/m^2) × resuspension rate (1/m) × outdoor dust invasion coefficient × effective dose conversion coefficient (Sv/Bq) × Respiration rate (m^3/s) × time on site (s) × decay correction (if correcting) (2)

Use equation (2) to find the dose for each nuclide, and total them.

(Parameter Conditions)

• Surface Contaminants Density

Assume that all nuclides in soil are on the top surface, and calculate from soil concentration

Contaminant density (Bq/m^2) = Sampling depth (0.05m) (5cm this time)) × soil density (kg/m^3) × concentration in soil (Bq/kg)

• Resuspension rate (1/m)

Established after studying the literature below.

Cited literature	Coefficient for resuspension from contaminated surfaces	Note	
IAEA SS 111-P-1.1, 1992	1.0E-06		
SRS	1.0E-07	Urban, non-farmland	
SRS	1.0E-05	Farmland soil	
NCRP-R-129, 1999	7.50E-10	Schools, parks, recreation facilities	Depth distribution assumption
NCRP-R-129, 1999	1.0E-06		Immediately after contamination
NCRP-R-129, 1999	3.3E-08	p.70	30 days after contamination
NCRP-R-129, 1999	1.0E-09	p.70	1000 days after contamination
Established this time	1.00E-06	Considering that students run around at school, which kicks up a lot of dust, initial values for settled on the ground surface of IAEA SS111 and NCRP-R129 on the safe side were used.	

● Respiration Rate

Established after studying the literature below.

Age	Light work		Sitting		
	m^3/h	m^3/s	m3/h	m3/s	Note
≥ age 17	1.500	4.17E-04	0.54	1.50E-04	ICRP72, CD1998
Age 15 (12 to under 17)	1.380	3.83E-04	0.48	1.33E-04	ICRP72, CD1998
Age 10 (7 to under 12)	1.120	3.11E-04	0.38	1.06E-04	ICRP72, CD1998
Age 5 (2 to under 7)	0.570	1.58E-04	0.32	8.89E-05	ICRP72, CD1998

Age 1 (1 to under 2)	0.350	9.72E-05	0.22	6.11E-05	ICRP72, CD1998
3 months (under age 1)	0.190	5.28E-05	0.09	2.50E-05	ICRP72, CD1998, sleep value because there is no sitting
Established this time	Ditto	Ditto	Ditto	Ditto	

■ Oral Ingestion

Assume that hands become contaminated, which is ingested via the mouth.

(Calculation Equation)

Effective dose (Sv) = Oral ingestion rate from hands (kg/d) × soil radioactive concentration (Bq/kg) × effective dose conversion coefficient (Sv/Bq) × ingestion time × (decay correction) (3)

(Parameter Conditions)

The table below shows values in literature on oral ingestion rate from hands, and values established after considering these.

Oral ingestion is not necessarily limited to time spend on the school field, so daily ingestion volume was used.

Literature Values and Established Values concerning Oral Ingestion Rates for Oral Ingestion by Hand Contamination

Cited literature	Oral ingestion rate
IAEA　SRS 44, 2005	25g/y (0.07g/d) Scenario RP: public places are covered with contaminants. Semi-infinite radiation sources.
RP-122 part2	Depends on age. 0-1: 0g/h, 1-2: 0.01g/h, 2-7: 0.01g/h, 7-12: 0.005g/h, 12-17: 0.005g/h, 17 and up: 0.005 Scenario playground: Athletic field or public place is covered with contaminants. 10cm semi-infinite level surface.
IAEA　SS 111-P-1.1, 1992	0.1g/d (child)
NCRP-R-129, 1999	0.05 (adult, suburb), 0.1 (child, suburb), 0.1 (adult, land in sparsely planted area), 0.2 (child, land in sparsely planted area)
EPA, OSWER Directive #9285.7-01a,1989	0.1g/d (adult), 0.2g/d (child)
EPA, OSWER Directive #9850.4,1989	
EPA/540/1-89/002, PB90-155581,1989	

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Established this time	g/d
≥ age 17	0.1
Age 15 (12 to under 17)	0.1

Age 10 (7 to under 12)	0.2
Age 5 (2 to under 7)	0.2
Age 1 (1 to under 2)	0.2
3 months (under age 1)	0

■ Invasion via Wounds

Assume that contamination invades the body via hand.

(Calculation Equation)

Effective dose (Sv) = Volume taken in via an injury (kg/event) × radiation concentration (Bq/kg) × effective dose conversion coefficient (Sv/Bq) × number of injuries × (decay correction) (4)

(Parameter Conditions)

- Assume one injury per month.
- For quantity of adherence to skin, assume the case of adherence to hands, where adherence is most likely, for the safe side.
- Assume that all dust adhering to the hand is injected into the blood in each injury (assess on safe side)
- Among all the skin areas dust is most likely to adhere to the hands, for which the literature below has an approximately 10mg concentration of dust. Therefore, assume that the injured place is on a hand, and all dust adhering to the hand is injected into the blood in each injury.
- Adult dose conversion coefficient is used. Even if overestimating from ICRP oral ingestion coefficients, child dose conversion coefficients are 10 times the adult conversion coefficients (10 times for iodine 131, two times for cesium 137). Therefore, even if estimating that a child dose of 10 times an adult's is too high a multiple, one can say that the dose calculated this time is sufficiently low. Incidentally, injection into the blood has a value slightly higher than for oral ingestion.

Cited literature	Quantity of hand contaminants	Note
IAEA SS 111-P-1.1, 1992	0.011g	Citation: Lepow et al. (1975)
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Established this time	0.011	

Results of a Follow-up Survey of Schools in Fukushima Prefecture

Survey date: April 14, 2011

No.	Koriyama City	Name of school surveyed	Soil Radioactivity (Bq/Kg wet weight)			Notes
			I-131	Cs		
				Cs-134	Cs-137	
1	Koriyama City	Koriyama Second Junior High School	1200	2800	3400	
2	Koriyama City	Saint-Paul's Kindergarten	2300	5500	6400	
3	Koriyama City	Kaoru Elementary School	3300	7200	8600	
4	Koriyama City	Koriyama First Junior High School	1700	3900	4500	
5	Koriyama City	Koriyama Third Junior High School	1900	3600	4100	
6	Motomiya City	Gohyakugawa Elementary School	2300	5100	5800	
7	Motomiya City	Motomiya 4th day-care center	3700	8600	9900	
8	Motomiya City	Wada Kindergarten	3100	6900	8200	
9	Motomiya City	Wada Elementary School	3400	7800	9100	
10	Nihonmatsu City	Ishii Kindergarten	3900	7700	8800	
11	Nihonmatsu City	Ishii Elementary School	1900	4300	5000	
12	Nihonmatsu City	Takeshita Elementary School	3100	5600	6400	
13	Nihonmatsu City	Matsugaoka day-care center	2700	5400	6300	
14	Nihonmatsu City	Sugita Elementary School	2100	3600	4200	

No.	Koriyama City	Name of school surveyed	Soil Radioactivity (Bq/Kg wet weight)			Notes
			I-131	Cs		
				Cs-134	Cs-137	
15	Nihonmatsu City	Sugita Kindergarten	2400	4500	5200	
16	Nihonmatsu City	Nihonmatsu Second Junior High School	2700	4900	5800	
17	Nihonmatsu City	Obama Junior High School	2600	2900	3400	
18	Fukushima City	Shimogawasaki Elementary School	2100	4700	5500	
19	Fukushima City	Okubo Elementary School	6200	6200	7500	
20	Fukushima City	Nankoudai Elementary School	4000	3200	3800	
21	Fukushima City	Onami Elementary School, Fukushima	3700	3000	3800	
22	Date City	Oguni Elementary School	6800	6700	8100	
23	Soma City	Tamano Kindergarten				These sites use the same field as No.25, so additional samples were not taken
24	Soma City	Tamano Junior High School	2900	3300	3900	
25	Soma City	Tamano Elementary School	2700	3200	3800	
26	Fukushima City	Okayama Elementary School	3500	2200	2800	
27	Fukushima City	Seishin Saniku day-care center	4600	4700	5600	
28	Fukushima City	Saniku Kindergarten	2200	480	620	
29	Date City	Tominari Elementary School	5000	3700	4300	

No.	Koriyama City	Name of school surveyed	Soil Radioactivity (Bq/Kg wet weight)			Notes
			I-131	Cs		
				Cs-134	Cs-137	
30	Fukushima City	Fukushima Yogo Gakko	4800	4300	5500	
31	Fukushima City	Oyama day-care center	3200	3800	4300	
32	Fukushima City	Oyama Elementary School	5000	5800	6800	
33	Fukushima City	Shinryo Junior High School	4600	6500	7700	
34	Fukushima City	Hirano Junior High School	3500	3300	4200	
35	Fukushima City	Fukushima Second Junior High School	2400	2340	2300	
36	Fukushima City	Fukushima University attached Kindergarten	2250	1340	1330	
37	Fukushima City	Fukushima University attached Junior High Schoo	2800	2590	2530	
38	Fukushima City	Fukushima Seikei Junior High School	2600	3660	3730	
39	Fukushima City	Gakuyo Junior High School	2180	2210	2270	
40	Fukushima City	Fukushima First Junior High School	2920	2900	3020	
41	Fukushima City	Fukushima Third Elementary School	3330	4710	4760	
42	Fukushima City	Fukushima Second Elementary School	2780	3140	3130	
43	Fukushima City	Sakura no Seibo Gakuin Kindergarden	2540	3520	3520	
44	Fukushima City	Sakura no Seibo Gakuin Elementary School	2580	2030	2070	
45	Fukushima City	Fukushima University attached Elementary Schoo	2550	3120	3120	

No.	Koriyama City	Name of school surveyed	Soil Radioactivity (Bq/Kg wet weight)			Notes
			I-131	Cs		
				Cs-134	Cs-137	
46	Fukushima City	Fukushima Prefectural School for the Blind	2990	3210	3180	
47	Fukushima City	Watari day-care center	3260	3480	3570	
48	Fukushima City	Kodomo no Ie Soramame	4090	5740	5930	
49	Fukushima City	Watari Junior High School	3250	4190	4200	
50	Fukushima City	Watari Kindergarten	3090	3840	3870	
51	Fukushima City	Sakura day-care center	2090	2560	2500	
52	Fukushima City	Watari Elementary School	2800	3420	3550	