Attachment3

Method of internal dose estimations for workers at Fukushima Daiichi Nuclear Power Station

August 2, 2011
Health Physics team, Head Office

Situations were arising in which it was difficult to perform internal dose estimations for workers in the Fukushima Daiichi Nuclear Power Station (hereinafter, 1F) accident because of no experience to deal with major nuclides of Cs-137 and I-131 in this accident (being beyond the scope of our manual in which Co-60 was treated as the target nuclide), multiple intake events during working operations and so on. Methods to cope with these situations are describes as follows.

1. Estimation method

(1) Measurement method

[Background]

Measurements of I-131 in the thyroids with NaI(Tl) survey meters were used in the internal dose estimations for workers who were examined with chair-type whole body counters having plastic scintillation detectors (hereinafter, WBC (PL)). However, we consider that these thyroid measurements can be appropriately used only for those who entered 1F from March to May in 2011, shortly after the Great Earthquake (all the dates in this document are in 2011 if not specified). The thyroid measurements using NaI(Tl) survey meters were performed as screening for workers engaged in operations at 1F.

For workers who were measured with another type of WBCs (mobile WBCs having NaI(Tl) scintillation detectors (hereinafter, referred to as WBC(NaI)) at Onahama and TEPCO's branch offices, these results were used for the internal dose estimations although such workers had received the measurements with the NaI(Tl) survey meters.

[Reason]

When measuring with WBC (PL), since the internal amount of I-131, which is one of the main nuclides, cannot be identified, also measure the dose of the thyroid gland at the neck.

WBC(PL) cannot measure I-131 due to its limitation on energy resolution.

(2) Method to determine the whole-body content of Cs from WBC(PL) (until the end of

June in 2011)

The WBCs(PL) at 1F were originally used in whole-body counting in which Co-60 was a target nuclide. Thus, a counting efficiency value of these WBCs for Cs-137 was estimated by using a phantom with Cs-137 solution and was then used for corrections of original results from the WBCs. When body surface contamination was suspected in the measurements with WBCs(PL), the contaminated area was shielded not to influence estimated whole-body content of Cs.

[Details]

Estimate using phantom efficiency corrected for Cs-137 with WBC (PL).

[Calculation of the whole-body content of Cs-137]

- The whole-body content in Cs-137 equivalent is obtained by dividing the net count rate from the WBC (PL) (cpm: count per minute) by the counting efficiency for Cs-137 (cpm/(γ/sec)) and the gamma emission yield of Cs-137 (0.85).
- The intake amount (Bq) is calculated by dividing the above value by the whole-body retention rate at the elapsed days from assumed intake date to measurement date.
- The effective dose is then calculated by multiplying the above value by the effective dose coefficient of Cs-137.

(3) Method to determine the whole-body content of Cs from WBC(PL) (until July in 2011 onward)

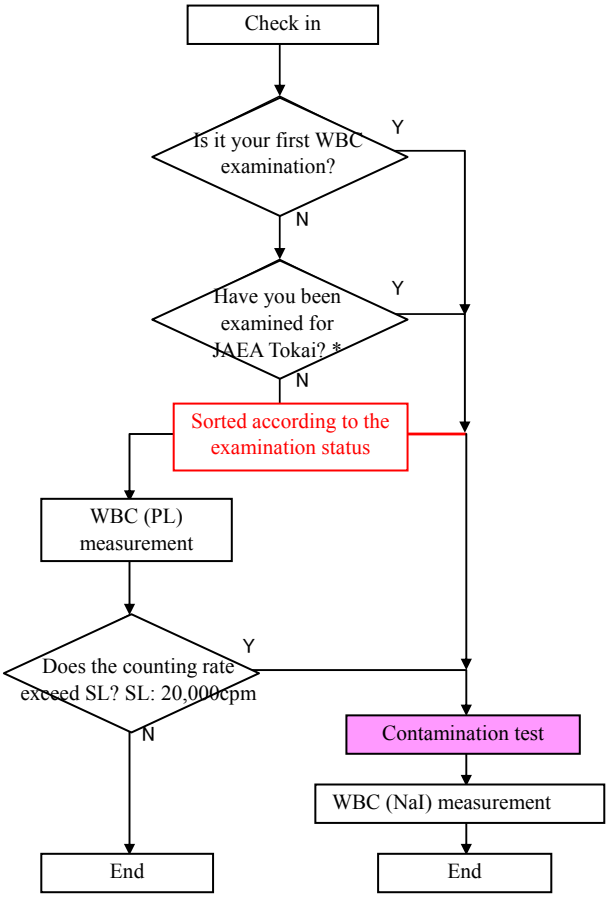
The results of the thyroid measurements with NaI(Tl) scintillation survey meters are not used for the purpose of internal dose estimations (I-131). Thus, the following method is applied.

WBC (PL) and WBC (NaI) will be installed at J-Village from July, but WBC (PL) and WBC (NaI) will be used together until there are enough units for smooth measurement with WBC (PL)*. Since workers with high internal exposure dose (over 20mSv) in the past are required to have additional intake evaluated, WBC (NaI) will be used for measurement during combined use. First measurers will also be measured with WBC (NaI). (Figure 1)

After enough units of WBC (PL) for screening measurement have been secured at J-Village, conduct measurement with WBC (NaI) on those who exceeded the screening level (SL) and evaluate the dose. SL is 20,000cpm at net value, and those below it are regarded as “below record level.”

In principle, there will be no correction of I-131 for intake from July onward. However, if I-131 is not detected due to the risk of additional intake when SL is

exceeded with WBC (PL) and measurement is conducted with WBC (NaI), there will be I-131 correction.



* Japan Atomic Energy Agency
Tokai Research and Development Center
Nuclear Science Research Institute

A contamination test is conducted to judge whether surface contamination affects the result of the WBC (NaI) measurement that evaluates the dose accurately.

After enough units have been secured for smooth measurement with only WBC (PL), the sorting in red will not take place, and screening measurement will be conducted with WBC (PL) in principle.

Figure 1. Screening measurement method

[Basis]

- The activity ratios of I-131 to Cs-137 in the environmental airborne concentration in early May and in early June were approximately 1 and 0.1, respectively. However, it is impossible to obtain the activity ratio from airborne monitoring later than the beginning of July because of no significant detection. Thus, the activity ratio later than July was assumed to be 0.01 (1%) from the time

trend of the ratio before that (and also considering the physical half-life of I-131).

- As a result, the contribution of I-131 to the total effective dose from Cs-134 and Cs-137 is calculated as 1.5% in July. Accordingly, the dose from I-131 can be neglected in the measurements later than July.
- I-131 in the thyroid was detected only in 4 out of 640 subjects who were measured with WBC(NaI) at Onahama in July. WBC(NaI) has a higher sensitivity for I-131 in the thyroid compared to a NaI(Tl) scintillation survey meter; however, it is designed for the whole-body counting (not for the thyroid counting). From these reasons, dose estimations of I-131 for the subjects without were not performed based on the thyroid measurements with the NaI(Tl) scintillation survey meter later than July.
- The recording level for internal doses used to be 2 mSv in individual monitoring in which internal dose measurements were conducted once every three month. At this time, the SL was set at the counting rate of 20,000 (cpm) for WBC(PL) corresponding to the effective dose of 0.5 mSv.

  0.5(mSv)／6.7E-06(mSv/Bq)×0.36(30 days residual percentage)／1.3(Bq/cpm)
  ＝20,666(cpm)

- Correction for I-131 when there is risk of additional intake is a measure taken because I-131 is not completely undetectable in the environment.

(4) Method to perform dose estimations for the intake of I-131 based on measurements with NaI(Tl) survey meter

[Background]

Measure to evaluate the amount of intake of I-131 deposited in the thyroid gland, and evaluate complying with “4.2 (3) Internal exposure estimation for the thyroid gland”. However, since measurement after a certain time from intake measures cesium distributed on the whole body instead of iodine deposited in the thyroid gland, measurement will not be conducted in July and onward.

For the same reason, when evaluating the internal exposure dose with I-131 with the result of the measurement conducted after more than 1 month from the intake day for those who entered 1F from March to early May, make corrections based on past statistics.

Since the NaI(Tl) scintillation survey meter is a device without a capability of the nuclide identification and the thyroid content of I-131 became negligibly small, we decided not to use the results from late measurements (conducted in July and onward) by this device for internal dose estimations.

[Estimation method]

Evaluate as follows.

(1) Measurement / estimation using the NaI survey meter

It is preferred to measure those who entered 1F from March to early May within several days after exiting 1F

- Place the tip of the NaI survey meter detector under the thyroid cartilage (Adam's apple) for the thyroid gland dose rate S (μSv/h).
- Subtract the background dose rate (μSv/h) from the thyroid gland dose rate S, and multiply it by the calibration factor (Bq/(μSv/h))* to determine the thyroid content of I-131(Bq).
- Calculate the intake amount of I-131 using a retention rate of I-131 in the thyroid content as a function of the elapsed time.
- Calculate the effective dose by multiplying the above value by the effective dose coefficient due to the intake via inhalation.

※Calibration factor of the NaI(Tl) scintillation survey meter that concerts a dose rate to the thyroid content of I-131.

Example: "The Emergency Exposure Medical Care Booklet", 20×10^3 (Bq/(μSv/h) for TCS-161.

(2) Estimation with correction based on the upper limit of the effective dose ratio of I-131 to Cs-137

The effective dose from Cs-137 were introduced from the measurements with WBC(Pl). For the subjects who have no results of thyroid measurements, the effective dose from I-131 was calculated using the upper limit of the effective dose ratio (I-131/Cs-137). The upper limit was given as the following function.

$$Y = -0.4633X + 18843$$

Y: Effective dose ratio (I-131/Cs-137)

X: Intake day (January 1, 1900 starting as 1)

This estimation method is applied for the following.

(I) Situations in which the proportion of the dose rate originating from I-131 deposited on the thyroid gland in the dose rate derived from NaI survey meter measurement is low

Ex.)

・Situations in which the influence of body surface contamination cannot be ignored
・Situations in which the influence of the amount of radioactivity of Cs-134 and Cs-137 inside the body cannot be ignored
・Situations in which the measurement timing is not appropriate, such as NaI survey meter measurement date is more than 1 month after the intake day

(II) Situations in which only WBC (Pl) measurement is conducted and NaI survey meter measurement is not (regular / offline WBC examination)

[Basis]

The following items however need to be carefully considered in internal dose estimations based on the measurements of I-131 by NaI(Tl) survey meters.

・The reading of the device was possibly influenced by Cs distributed in the whole-body, resulting in overestimations of the internal dose.
・Since measurement is overestimated if body surface contamination is picked up, it is not recommended to conduct measurement immediately after exiting 1F, but considering the half-life of I-131, measurement should be conducted within several days after exiting 1F.
・Especially, this influence would become significant in late measurements; the reading was expected be almost originated from Cs-137 in the measurements later than mid-May.

Given the above items, for measurement / estimation using the NaI survey meter, it is preferred to measure those who entered 1F from March to early May within several days after exiting 1F, and measurement conducted later than that may result in overestimation or underestimation of the effective dose estimation with I-131.

See attachment 1-4 for the basis of the corrected estimation based on statistics (effective dose estimation with I-131).

(5) Estimation method using WBC (NaI)

[Background]

Although the division ability (energy resolution) of nuclides is relatively lower than Ge, conduct dose assessment from the amount of internal intake by nuclide since estimation for each nuclide is possible. The estimation procedures shall comply with “4.2 (1) Internal exposure estimation with external counting”. If body contamination is found where it cannot be blocked by the detector (hair on the back of the head, etc.), said area

is to be shielded for measurement, accordingly.

See "1. (4) Estimation method with WBC (PL) (for measurement in July and onward)" for measurements from July 1.

WBC(NaI) is a nuclide-selective device that can identify/quantify Cs-137, Cs-134 and I-131 separately. The body content of each nuclide was directly used for internal dose estimations.

[Estimation method]

Estimate as follows.

- Quantify the body content of each nuclides from the measurements by WBC(NaI).
- Divide the internal amount by the whole body residual percentage to derive the amount of intake (Bq).
- Multiply the amount of intake by the effective dose coefficient (mSv/Bq) to derive the depositary effective dose (mSv).

(6) Detailed measurement

[Background]

The internal dose estimations were performed based on detailed measurements at JAEA with a WBC having two Ge detectors (WBC(Ge)) for those whose internal doses exceeded 20 mSv in previous estimations based on results from WBC(NaI) or WBC(PL). In this case, the behavior survey was performed in order to determine a realistic intake scenario during the working period.

[Basis]

As it is written that "The limit is to be expressed as an effective dose of 20mSv per year on average over 5 years (100mSv in 5 years)" under Paragraph (244) dose limit in ICRP103, the dose limit of occupational exposure is to be the same as this figure. In Paragraph (241) of ICRP103, it is written "Individuals are to be notified of information concerning measures to reduce radiation risks and radiation levels. Estimation of individual dose is to be conducted," as the requirement for radiological protection for doses greater than 20mSv and less than 100mSv, and 20mSv is the minimum value of this standard.

For those exceeding the annual intake limit of 20mSv, conduct detailed measurement with WBC (Ge), and confirm that the dose limit is not exceeded by combining it with external exposure dose. The intake day is conservatively set as the work start date when workers were interviewed, but set the correct intake day from the behavioral survey for

re-estimation, followed by detailed measurement with WBC (Ge).

Based on the above, the flow of measurement / estimation with WBC (NaI) is shown in Figures 3 and 4.

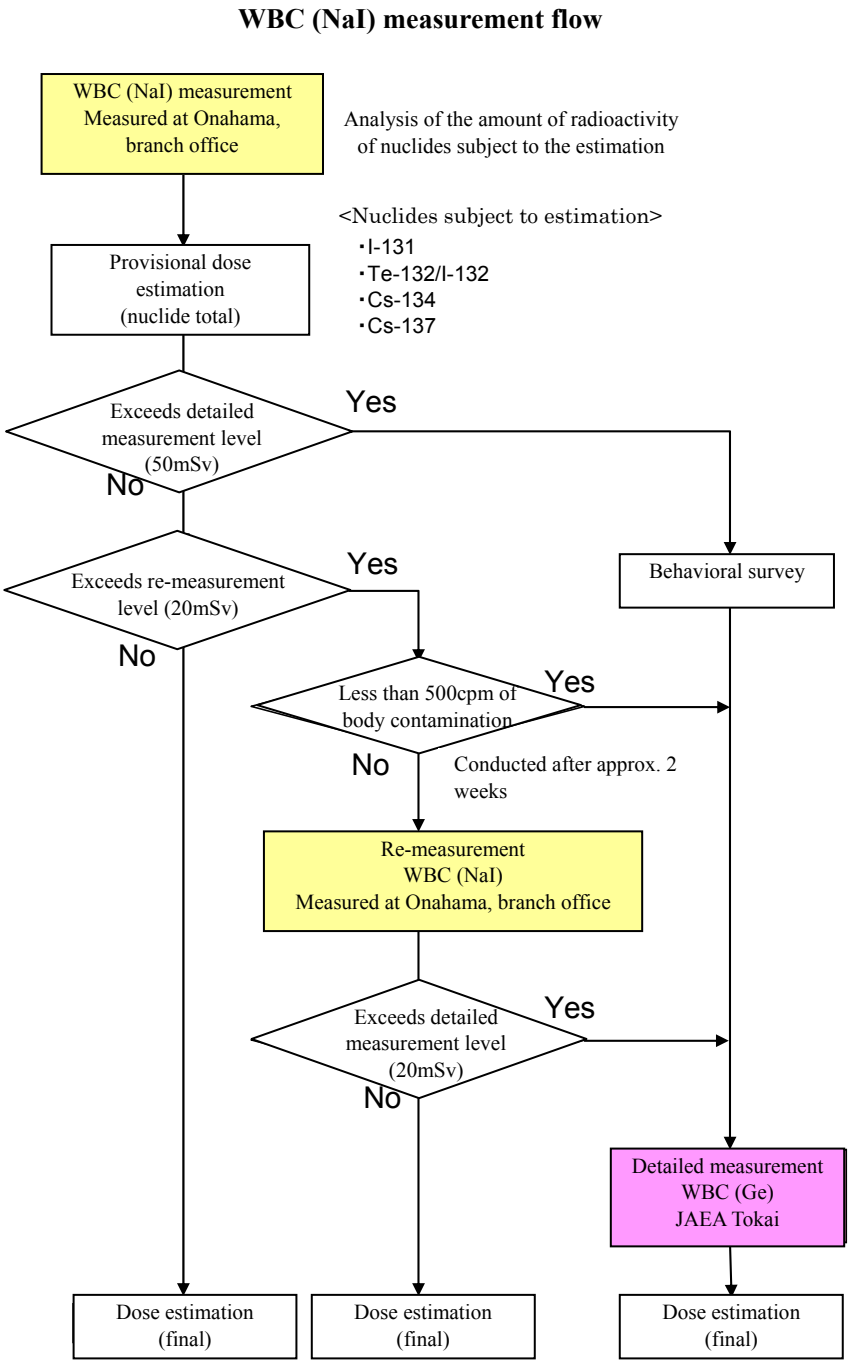


Figure 3. WBC measurement / estimation flow (initial)

WBC (NaI) measurement flow

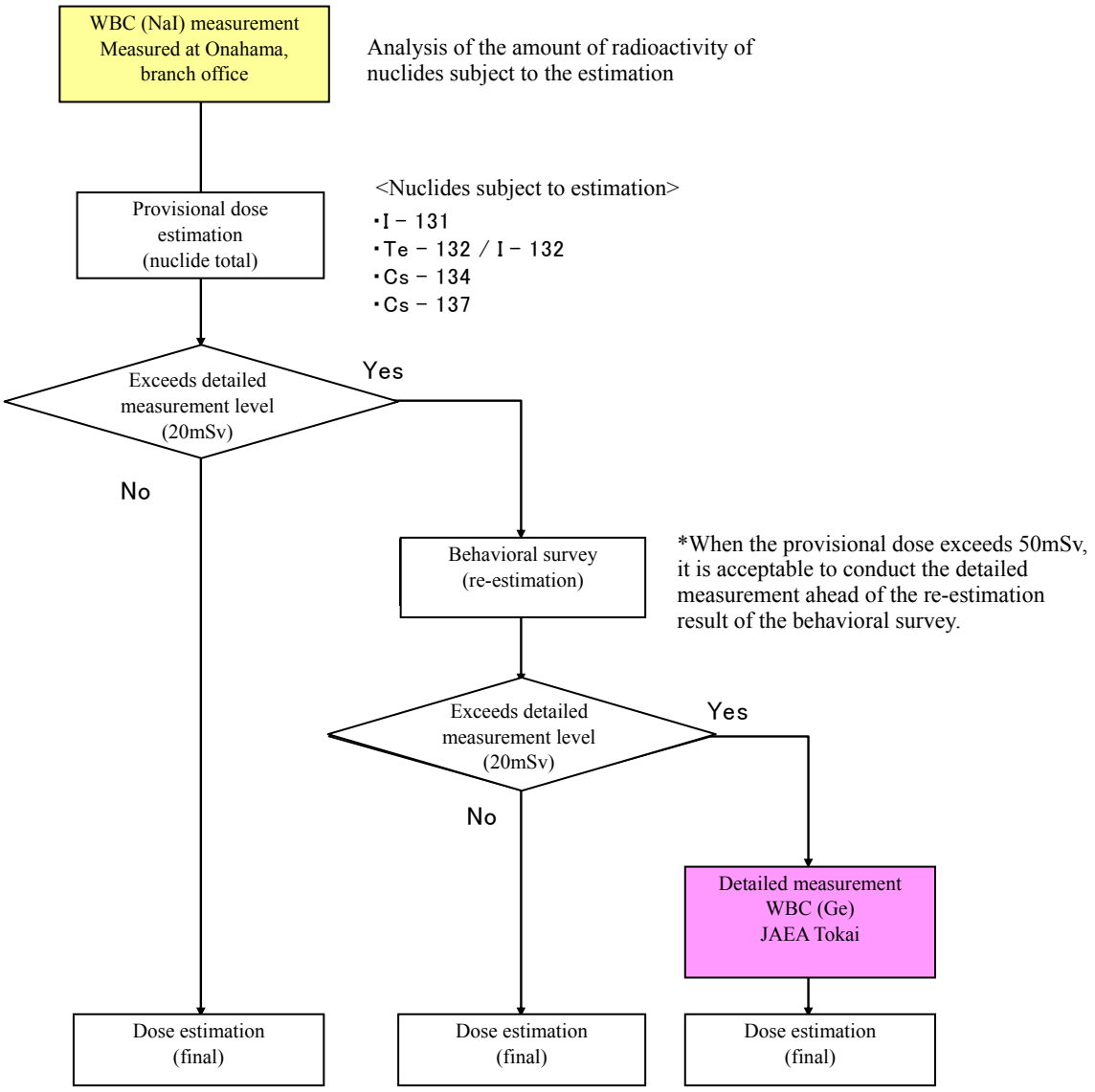


Figure 4. WBC measurement / estimation flow
(when body contamination does not occur any more)

2. Estimation conditions

Estimation conditions used in the internal exposure dose estimation are as shown in Attachment 1.

END

Attachment 1

Calculation conditions in internal dose estimations

Items	Descriptions	Reference
1. Nuclides to be measured (assumed chemical form) ※1		
(1) WBC (NaI) measurement targets	・I-131 (vapor) ・Te-132/I-132 (vapor) ・Cs-137 (all chemical compounds: type F) ・Cs-134 (all chemical compounds: type F)	
(2) WBC (PL) measurement targets	・I-131 (steam vapor) ※2 ・Cs-137 (all chemical compounds: type F)※3	
2. Effective dose coefficient	Attached table 2 column 2 “Effective dose coefficient for inhaled intake” in the announcement stipulating the dose limit based on the provisions in the rule on the installation and operation of commercial power reactors Effective dose coefficients due to inhalation shown in the announcement … (based on ICRP Publication 68)	Attached table 1
3. Retention rate (whole-body/thyroid)	Retention rates of nuclides for whole-body and thyroid extracted from the internal dose calculation code “MOMDAL3” developed by National Institute of Radiological Sciences	Attached table 2
4. Intake day	When the work start date is in March or April: Intake day is the work start date. If work is started before March 11, the intake day will be March 12. ※5	
	When the work start date is in May and onward: Intake day is the day halfway between the work start date and end date. ※6	
5. Correction when I-131 cannot be detected due to delay of WBC (NaI) measurement	See attachment 1-2	
6. Residue from the previous intake events	See attachment 1-3	
7. Significant digit for the figures in dose estimation	2 digits after the decimal point (round off the third digit)	
8. Corrected estimation based on statistics (Effective dose estimation with I-131)	See attachment 1-4	

※1 Target nuclides based on workplace monitoring and results of detailed measurements with WBC(Ge).

※2 (The thyroid content of I-131) Based on thyroid measurements with NaI(Tl) scintillation survey meter

※3 (The whole-body content of Cs-137) based on measurements with WBC (Pl) (cpm: net count rate)

※4 From the standpoint of the estimation conditions of the detailed measurement (JAEA) and the openness of the estimation code, use the internal residual percentage of "MONDAL3" of said code. However, use the figure in "IDEC Ver.1" for the internal residual percentage of Te-132 (I-132) which is not in MONDAL3.

※5 The radioactive material concentration in the environment drastically increased and decreased after the hydrogen explosion, and has gradually decreased following the event. Therefore, as it is assumed that the intake of those entering the site in March and April is slanted toward the first half, the work start date will be set for the intake day. Since the first hydrogen explosion was on March 12, the intake day is March 12 at the earliest.

※6 In regard to iodine which is one of the major nuclides in internal exposure, since the radioactive material concentration in the environment is sufficiently low in May and onward, the intake day is set as the day halfway between the work period.

Attached table 1 Effective dose coefficient

Nuclides	Effective dose coefficient (mSv/Bq)
I-131 (steam)	2.0×10^{-5}
Te-132/I-132 (steam)	$5.1\times10^{-6}/3.2\times10^{-7}$
Cs-137 (all chemical compounds: type F)	6.7×10^{-6}
Cs-134 (all chemical compounds: type F)	9.6×10^{-6}

Attached table 2. Internal residual percentage (whole body or thyroid gland residual percentage)

残留率関数 Residual percentage function	31		Te-132	I-132	Cs-137	Cs-134	Whole body
経過日数	Lapsed days	Whole body	Thyroid gland	Whole body	Whole body	Whole body	
0.2	8.11E-01	1.04E-01	9.10E-01		7.58E-01	7.58E-01	
1	3.31E-01	2.29E-01	5.90E-01	5.6E-01	5.97E-01	5.96E-01	
2	2.41E-01	2.23E-01	3.70E-01	3.4E-01	5.05E-01	5.04E-01	
3	2.12E-01	2.03E-01	2.60E-01	2.4E-01	4.65E-01	4.63E-01	
4	1.92E-01	1.85E-01	1.90E-01	1.7E-01	4.45E-01	4.43E-01	
5	1.75E-01	1.68E-01	1.40E-01	1.3E-01	4.34E-01	4.32E-01	
6	1.60E-01	1.53E-01	1.10E-01	9.9E-02	4.26E-01	4.24E-01	
7	1.46E-01	1.39E-01	8.90E-02	8.1E-02	4.21E-01	4.18E-01	
8	1.34E-01	1.27E-01	7.10E-02	6.4E-02	4.16E-01	4.13E-01	
9	1.23E-01	1.15E-01	5.70E-02	5.2E-02	4.12E-01	4.09E-01	
10	1.12E-01	1.05E-01	4.50E-02	4.0E-02	4.09E-01	4.05E-01	
11	1.03E-01	9.57E-02	3.61E-02	3.3E-02	4.05E-01	4.02E-01	
12	9.40E-02	8.71E-02	2.80E-02	2.6E-02	4.02E-01	3.98E-01	
13	8.60E-02	7.93E-02	2.35E-02	2.1E-02	4.00E-01	3.95E-01	
14	7.86E-02	7.22E-02	1.80E-02	1.6E-02	3.97E-01	3.92E-01	
15	7.19E-02	6.58E-02	1.40E-02	1.3E-02	3.94E-01	3.89E-01	
16	6.57E-02	5.99E-02	1.20E-02	1.1E-02	3.92E-01	3.86E-01	
17	6.01E-02	5.45E-02	9.35E-03	8.5E-03	3.89E-01	3.83E-01	
18	5.49E-02	4.97E-02	7.14E-03	6.5E-03	3.87E-01	3.81E-01	
19	5.01E-02	4.52E-02	6.25E-03	5.6E-03	3.84E-01	3.78E-01	
20	4.58E-02	4.12E-02	4.50E-03	4.1E-03	3.82E-01	3.75E-01	
21	4.19E-02	3.75E-02	3.88E-03	3.5E-03	3.79E-01	3.72E-01	
22	3.82E-02	3.42E-02	3.30E-03	3.0E-03	3.77E-01	3.70E-01	
23	3.49E-02	3.11E-02	2.39E-03	2.2E-03	3.74E-01	3.67E-01	
24	3.19E-02	2.84E-02	2.00E-03	1.8E-03	3.72E-01	3.64E-01	
25	2.91E-02	2.58E-02	1.69E-03	1.5E-03	3.70E-01	3.62E-01	
26	2.66E-02	2.35E-02	1.40E-03	1.3E-03	3.67E-01	3.59E-01	
27	2.43E-02	2.14E-02	9.52E-04	8.6E-04	3.65E-01	3.57E-01	
28	2.22E-02	1.95E-02	7.90E-04	7.1E-04	3.63E-01	3.54E-01	
29	2.02E-02	1.78E-02	6.49E-04	5.9E-04	3.60E-01	3.51E-01	
30	1.85E-02	1.62E-02	5.40E-04	4.9E-04	3.58E-01	3.49E-01	
31	1.68E-02	1.48E-02	4.27E-04	3.8E-04	3.56E-01	3.46E-01	
32	1.54E-02	1.35E-02	3.38E-04	3.0E-04	3.53E-01	3.44E-01	
33	1.40E-02	1.23E-02	2.67E-04	2.4E-04	3.51E-01	3.41E-01	
34	1.28E-02	1.12E-02	2.12E-04	1.9E-04	3.49E-01	3.39E-01	
35	1.17E-02	1.02E-02	1.68E-04	1.5E-04	3.47E-01	3.37E-01	
36	1.07E-02	9.29E-03	1.33E-04	1.2E-04	3.45E-01	3.34E-01	
37	9.73E-03	8.46E-03	1.06E-04	9.5E-05	3.42E-01	3.32E-01	
38	8.88E-03	7.71E-03	7.81E-05	9.5E-05	3.40E-01	3.29E-01	
39	8.10E-03	7.03E-03	7.81E-05	7.1E-05	3.38E-01	3.27E-01	
40	7.39E-03	6.41E-03	5.81E-05	5.3E-05	3.36E-01	3.25E-01	
41	6.74E-03	5.84E-03	4.31E-05	3.9E-05	3.34E-01	3.22E-01	
42	6.15E-03	5.32E-03	4.31E-05	3.9E-05	3.32E-01	3.20E-01	
43	5.61E-03	4.85E-03	3.21E-05	2.9E-05	3.30E-01	3.18E-01	
44	5.11E-03	4.42E-03	2.38E-05	2.2E-05	3.27E-01	3.15E-01	
45	4.67E-03	4.03E-03	1.77E-05	1.6E-05	3.25E-01	3.13E-01	
46	4.26E-03	3.67E-03	1.77E-05	1.6E-05	3.23E-01	3.11E-01	
47	3.88E-03	3.35E-03	1.31E-05	1.2E-05	3.21E-01	3.09E-01	
48	3.54E-03	3.05E-03	1.31E-05	1.2E-05	3.19E-01	3.06E-01	
49	3.23E-03	2.78E-03	8.77E-06	7.9E-05	3.17E-01	3.04E-01	
50	2.94E-03	2.53E-03	8.77E-06	7.9E-06	3.15E-01	3.02E-01	

残留率関数	Residual percentage function	31	Te-132	I-132	Cs-137	Cs-134	
経過日数	Lapsed days	Whole body	Thyroid gland	Whole body	Whole body	Whole body	Whole body
51	2.68E-03	2.31E-03	5.88E-06	5.3E-06	3.13E-01	3.00E-01	
52	2.45E-03	2.10E-03	3.95E-06	3.6E-06	3.11E-01	2.98E-01	
53	2.23E-03	1.92E-03	3.95E-06	3.6E-06	3.09E-01	2.96E-01	
54	2.04E-03	1.75E-03	2.65E-06	2.4E-06	3.07E-01	2.93E-01	
55	1.86E-03	1.59E-03	2.65E-06	2.4E-06	3.05E-01	2.91E-01	
56	1.69E-03	1.45E-03	1.78E-06	1.6E-06	3.03E-01	2.89E-01	
57	1.54E-03	1.32E-03	1.78E-06	1.6E-06	3.01E-01	2.87E-01	
58	1.41E-03	1.21E-03	1.19E-06	1.1E-06	3.00E-01	2.85E-01	
59	1.28E-03	1.10E-03	1.19E-06	1.1E-06	2.98E-01	2.83E-01	
60	1.17E-03	1.00E-03	8.00E-07	7.2E-07	2.96E-01	2.81E-01	
61	1.07E-03	9.14E-04	8.00E-07		2.94E-01	2.79E-01	
62	9.73E-04	8.33E-04	8.00E-07		2.92E-01	2.77E-01	
63	8.87E-04	7.60E-04	8.00E-07		2.90E-01	2.75E-01	
64	8.09E-04	6.92E-04	8.00E-07		2.88E-01	2.73E-01	
65	7.38E-04	6.31E-04	8.00E-07		2.87E-01	2.71E-01	
66	6.73E-04	5.75E-04	8.00E-07		2.85E-01	2.69E-01	
67	6.13E-04	5.24E-04	8.00E-07		2.83E-01	2.67E-01	
68	5.59E-04	4.78E-04	8.00E-07		2.81E-01	2.65E-01	
69	5.10E-04	4.36E-04	8.00E-07		2.79E-01	2.63E-01	
70	4.65E-04	3.97E-04	8.00E-07		2.78E-01	2.61E-01	
71	4.24E-04	3.62E-04	8.00E-07		2.76E-01	2.59E-01	
72	3.86E-04	3.30E-04	8.00E-07		2.74E-01	2.58E-01	
73	3.52E-04	3.01E-04	8.00E-07		2.72E-01	2.56E-01	
74	3.21E-04	2.74E-04	8.00E-07		2.71E-01	2.54E-01	
75	2.93E-04	2.50E-04	8.00E-07		2.69E-01	2.52E-01	
76	2.67E-04	2.28E-04	8.00E-07		2.67E-01	2.50E-01	
77	2.43E-04	2.08E-04	8.00E-07		2.65E-01	2.48E-01	
78	2.22E-04	1.89E-04	8.00E-07		2.64E-01	2.47E-01	
79	2.02E-04	1.73E-04	8.00E-07		2.62E-01	2.45E-01	
80	1.84E-04	1.57E-04	8.00E-07		2.60E-01	2.43E-01	
81	1.68E-04	1.43E-04	8.00E-07		2.59E-01	2.41E-01	
82	1.53E-04	1.31E-04	8.00E-07		2.57E-01	2.40E-01	
83	1.40E-04	1.19E-04	8.00E-07		2.55E-01	2.38E-01	
84	1.27E-04	1.09E-04	8.00E-07		2.54E-01	2.36E-01	
85	1.16E-04	9.91E-05	8.00E-07		2.52E-01	2.35E-01	
86	1.06E-04	9.03E-05	8.00E-07		2.51E-01	2.33E-01	
87	9.66E-05	8.23E-05	8.00E-07		2.49E-01	2.31E-01	
88	8.80E-05	7.50E-05	8.00E-07		2.47E-01	2.30E-01	
89	8.03E-05	6.84E-05	8.00E-07		2.46E-01	2.28E-01	
90	7.32E-05	6.24E-05	8.00E-07		2.44E-01	2.26E-01	
91	6.67E-05	5.69E-05	8.00E-07		2.43E-01	2.25E-01	
92	6.08E-05	5.18E-05	8.00E-07		2.41E-01	2.23E-01	
93	5.54E-05	4.72E-05	8.00E-07		2.40E-01	2.21E-01	
94	5.05E-05	4.31E-05	8.00E-07		2.38E-01	2.20E-01	
95	4.61E-05	3.93E-05	8.00E-07		2.37E-01	2.18E-01	
96	4.20E-05	3.58E-05	8.00E-07		2.35E-01	2.17E-01	
97	3.83E-05	3.26E-05	8.00E-07		2.34E-01	2.15E-01	
98	3.49E-05	2.97E-05	8.00E-07		2.32E-01	2.14E-01	
99	3.18E-05	2.71E-05	8.00E-07		2.31E-01	2.12E-01	
100	2.90E-05	2.47E-05	8.00E-07		2.29E-01	2.10E-01	

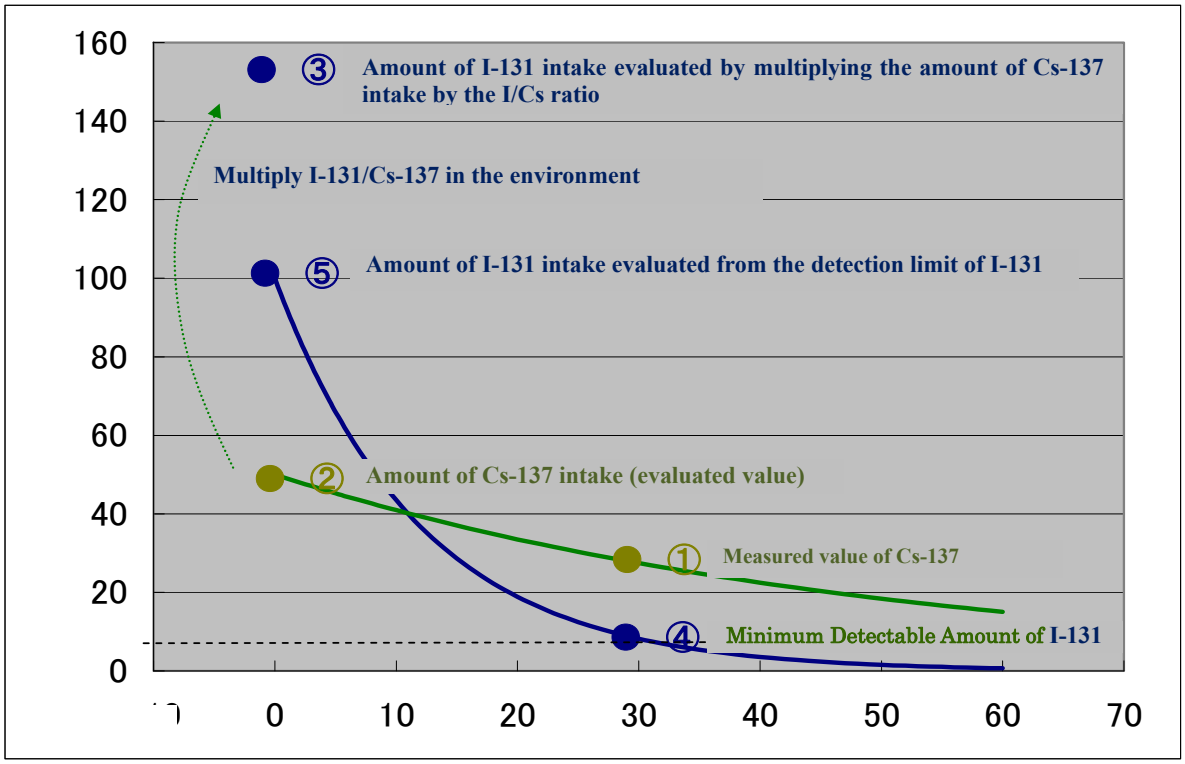
Data for the 60th day is entered for the residual percentage of Te-132 for the 61st day and onward.

Attachment 1-2 Correction method when I-131 is not detected due to delay of the measurement timing

Since the half-life of I-131 is short at 8 days, it cannot be sometimes found in late measurements. Here, the correction method for when I-131 is not detected is stipulated.

1. If the intake timing is March to June

When the intake day is in March thru June and I-131 is not detected, make corrections by deriving the amount of I-131 intake through calculation and evaluate the effective dose.



(1)Correction using the I-131/Cs-137 ratio based on environmental data

Make corrections as follows when I-131 is not detected and Cs-137 is detected.

- Divide the measured value of Cs-137 by the retention rate of Cs-137 to derive the amount of Cs-137 intake. (①→②)
- Multiply the amount of Cs-137 intake by the I-131/C-137 ratio* in the environment to derive the amount of I-131 intake. (②→③)

(2)Correction using the detection limit of I-131

- Divide the detection limit of I-131 by the residual percentage of I-131 to derive the amount of I-131 intake. (④→⑤)

(3)Determining the corrected value

・Compare the value corrected based on environmental data and value corrected based on the detection limit, and set the lower value as the amount of I-131 intake.

(4)Estimation from the data of the amount of intake of workers from around the same time

・It is also acceptable to evaluate from the data of the amount of intake of workers from around the same time.

※I-131/Cs-137 ratio

Set the “I-131/Cs-137 abundance ratio” from the environmental data measured on said intake day. In order to prevent the dispersion of data, calculate the 5-day running average of the intake day and 2 days before and after the intake day. As a reference, show the trend of dust contamination of I-131 and Cs-137 in the environment in the below chart and show the “I-131/Cs-137 abundance ratio” in the below table. The area where I-131 is not plotted at the right end of the graph is data that is below the detection limit.

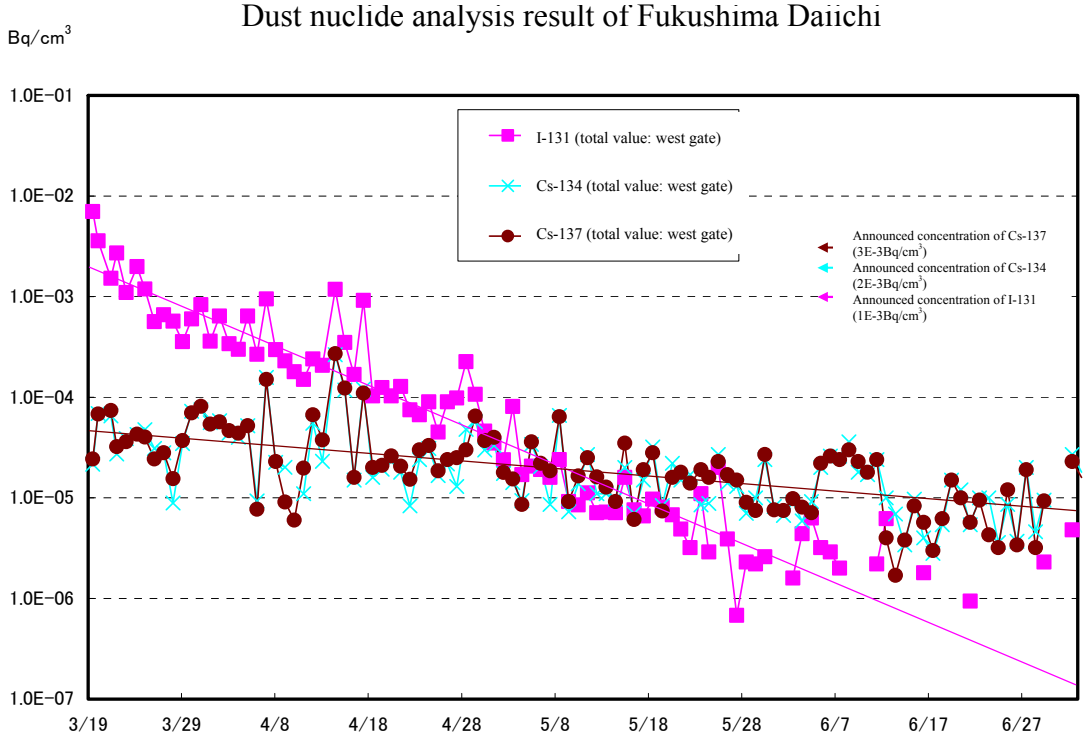


Figure. Dust nuclide analysis result of Fukushima Daiichi Nuclear Power Station

2. If the intake timing is July onward

Since there is an increasing amount of data with I-131 concentration below the detection limit in the dust nuclide analysis result for July onward, the I-131/Cs-137 ratio for July onward is 0.01 according to the trend. Assuming that the effective dose equivalent coefficient of I-131 is 3 times that of Cs-137 and the same amount of Cs-137 and Cs-134 was taken in, contribution of I-131 in the effective dose is 1-2%. Therefore, as the dose contribution of I-131 in July and onward is sufficiently low, it can be ignored for the dose estimation.

Table. Ratio of I-131 to Cs-137 using 1F environment data (on-site aerial radioactive materials contamination density)

	I-131			Cs-137				I-131／Cs-137				Intake location
	気体状	粒子状	合	Gaseous	Particl	Total	Gaseous	Particl	Total	Current day	5-day runnin	
3月11日			3/11						121.7	3/19データを採用		Data collected on 3/19
3月12日			3/12						121.7	3/19データを採用		
3月13日			3/13						121.7	3/19データを採用		
3月14日			3/14						121.7	3/19データを採用		
3月15日			3/15						121.7	3/19データを採用		
3月16日			3/16						121.7	3/19データを採用		
3月17日			3/17						121.7	3/19データを採用		
3月18日			3/18						121.7	3/19データを採用		
3月19日	5.90E-03	1.10	3/19	)E-03	-	2.40E-05	2.40E-05	291.7	121.7	事務本館北側		North side of main administration building
3月20日	2.30E-03	1.30	3/20	)E-03	3.90E-05	2.90E-05	6.80E-05	52.9	112.1	事務本館北側		
3月21日	1.50E-03	9.20	3/21	1E-03	3.60E-05	3.80E-05	7.40E-05	20.4	95.8	事務本館北側		
3月22日	2.20E-03	4.70	3/22	7E-03	1.30E-05	1.90E-05	3.20E-05	83.4	46.8	正門		Main gate
3月23日	6.70E-04	4.30	3/23	)E-03	2.30E-05	1.30E-05	3.60E-05	30.6	42.2	正門		
3月24日	1.50E-03	5.00	3/24	)E-03	3.10E-05	1.20E-05	4.30E-05	46.5	42.6	正門		
3月25日	8.80E-04	3.20	3/25	)E-03	2.40E-05	1.60E-05	4.00E-05	30.0	30.6	正門		
3月26日	3.00E-04	2.60	3/26	)E-04	8.80E-06	1.60E-05	2.48E-05	22.6	31.8	正門		
3月27日	4.50E-04	2.10	3/27	)E-04	1.40E-05	1.40E-05	2.80E-05	23.6	24.5	正門		
3月28日	3.60E-04	2.10	3/28	)E-04	8.10E-06	7.50E-06	1.56E-05	36.5	20.2	西門		West gate
3月29日	2.40E-04	1.20	3/29	)E-04	2.30E-05	1.40E-05	3.70E-05	9.7	17.7	西門		
3月30日	4.10E-04	1.90	3/30	)E-04	4.00E-05	3.00E-05	7.00E-05	8.6	14.4	西門		
3月31日	6.40E-04	1.90	3/31	)E-04	4.50E-05	3.60E-05	8.10E-05	10.2	9.3	西門		
4月1日	2.50E-04	1.10	4/1	)E-04	3.40E-05	2.00E-05	5.40E-05	6.7	8.8	西門		
4月2日	4.30E-04	2.10	4/2	)E-04	3.70E-05	2.00E-05	5.70E-05	11.2	8.4	西門		
4月3日	2.30E-04	1.10	4/3	)E-04	3.10E-05	1.60E-05	4.70E-05	7.2	8.9	西門		
4月4日	2.00E-04	1.00	4/4	)E-04	2.80E-05	1.60E-05	4.40E-05	6.8	13.3	西門		
4月5日	4.20E-04	2.20	4/5	)E-04	2.10E-05	3.10E-05	5.20E-05	12.3	12.3	西門		
4月6日	2.00E-04	6.70	4/6	7E-04	-	9.30E-06	9.30E-06	28.7	13.4	西門		
4月7日	7.80E-04	1.70	4/7	)E-04	-	1.50E-04	1.50E-04	6.3	17.1	西門		
4月8日	2.10E-04	8.70	4/8	7E-04	1.40E-05	9.00E-06	2.30E-05	12.9	20.6	西門		
4月9日	1.50E-04	8.00	4/9	)E-04	-	9.10E-06	9.10E-06	25.3	16.4	西門		
4月10日	1.30E-04	4.90	4/10	)E-04	-	6.00E-06	6.00E-06	29.8	15.8	西門		
4月11日	1.10E-04	4.00	4/11	)E-04	1.40E-05	5.80E-06	1.98E-05	7.6	14.4	西門		
4月12日	1.30E-04	1.10	4/12	)E-04	2.90E-05	3.80E-05	6.70E-05	3.6	10.2	西門		
4月13日	9.70E-05	1.10	4/13	7E-04	1.10E-05	2.60E-05	3.70E-05	5.6	4.8	西門		
4月14日	7.60E-04	4.20	4/14	8E-03	8.10E-05	1.90E-04	2.71E-04	4.4	5.4	西門		
4月15日	2.20E-04	1.30	4/15	)E-04	8.10E-05	4.20E-05	1.23E-04	2.8	6.3	西門		
4月16日	1.10E-04	5.80	4/16	8E-04	1.60E-05	-	1.60E-05	10.5	6.2	西門		
4月17日	5.70E-04	3.50	4/17	)E-04	-	1.10E-04	1.10E-04	8.4	6.6	西門		
4月18日	7.10E-05	3.20	4/18	3E-04	1.40E-05	6.00E-06	2.00E-05	5.2	6.8	西門		
4月19日	5.00E-05	7.50	4/19	5E-04	1.40E-05	7.00E-06	2.10E-05	6.0	5.9	西門		
4月20日	7.00E-05	3.30	4/20	3E-04	1.70E-05	9.10E-06	2.61E-05	3.9	5.2	西門		
4月21日	7.60E-05	5.20	4/21	8E-04	1.30E-05	7.60E-06	2.06E-05	6.2	4.6	西門		
4月22日	3.70E-05	3.80	4/22	)E-05	9.00E-06	6.30E-06	1.53E-05	4.9	4.0	西門		
4月23日	4.00E-05	2.70	4/23	)E-05	1.50E-05	1.50E-05	3.00E-05	2.2	3.7	西門		
4月24日	4.80E-05	4.20	4/24	)E-05	1.70E-05	1.60E-05	3.30E-05	2.7	3.2	西門		
4月25日	3.10E-05	1.40	4/25	)E-05	1.00E-05	8.60E-06	1.86E-05	2.4	3.0	西門		
4月26日	5.00E-05	4.00	4/26	)E-05	1.40E-05	1.00E-05	2.40E-05	3.8	4.1	西門		
4月27日	5.10E-05	4.70	4/27	)E-05	1.20E-05	1.30E-05	2.50E-05	3.9	3.9	西門		
4月28日	1.60E-04	6.60	4/28	5E-04	-	3.00E-05	3.00E-05	7.5	3.6	西門		
4月29日	6.30E-05	4.40	4/29	7E-04	4.50E-05	2.00E-05	6.50E-05	1.6	3.0	西門		
4月30日	3.30E-05	1.30	4/30	)E-05	2.50E-05	1.20E-05	3.70E-05	1.2	2.5	西門		
5月1日	2.3E-05	1.2E	5/1	E-05	1.7E-05	2.3E-05	4.0E-05	0.9	2.1	西門		
5月2日	1.5E-05	8.9E	5/2	E-05	1.0E-05	7.9E-06	1.8E-05	1.3	2.1	西門		
5月3日	4.0E-05	4.1E	5/3	E-05	7.2E-06	8.2E-06	1.5E-05	5.3	2.0	西門		
5月4日	8.7E-06	8.3E	5/4	E-05	8.6E-06		8.6E-06	2.0	2.0	西門		
5月5日	1.2E-05	8.6E	5/5	E-05	2.1E-05	1.5E-05	3.6E-05	0.6	1.9	西門		
5月6日	1.0E-05	9.1E	5/6	E-05	1.2E-05	1.0E-05	2.2E-05	0.9	0.9	西門		
5月7日	9.0E-06	7.0E	5/7	E-05	1.2E-05	6.6E-06	1.9E-05	0.9	0.7	西門		
5月8日	1.3E-05	1.1E	5/8	E-05	2.9E-05	3.5E-05	6.4E-05	0.4	0.7	西門		
5月9日	5.1E-06	4.1E	5/9	E-06	9.2E-06		9.2E-06	1.0	0.6	西門		
5月10日	4.8E-06	3.7E	5/10	E-06	8.3E-06	8.2E-06	1.7E-05	0.5	0.6	西門		
5月11日	7.3E-06	3.9E	5/11	E-05	1.1E-05	1.4E-05	2.5E-05	0.4	0.6	西門		
5月12日	4.7E-06	2.4E	5/12	E-06	1.0E-05	6.1E-06	1.6E-05	0.4	0.5	西門		
5月13日	4.9E-06	2.3E	5/13	E-06	7.9E-06	4.9E-06	1.3E-05	0.6	0.5	西門		
5月14日			5/14	E-06			9.2E-06	0.8	0.7	西門		
5月15日			5/15	E-05			3.5E-05	0.5	0.7	西門		
5月16日			5/16	E-06			6.1E-06	1.2	0.6	西門		
5月17日			5/17	E-06			1.9E-05	0.3	0.7	西門		
5月18日			5/18	E-06			2.8E-05	0.3	0.7	西門		
5月19日			5/19	E-06			7.4E-06	1.1	0.5	西門		
5月20日			5/20	E-06			1.6E-05	0.4	0.5	西門		
5月21日			5/21	E-06			1.8E-05	0.3	0.5	西門		
5月22日			5/22	E-06			1.4E-05	0.2	0.3	西門		
5月23日			5/23	E-06			1.9E-05	0.4	0.4	西門		
5月24日			5/24	E-06			1.6E-05	0.2	0.4	西門		Near MP5
5月25日			5/25	E-05			2.3E-05	0.9	0.3	ＭＰ５付近		West gate
5月26日			5/26	E-06			1.7E-05	0.2	0.3	西門		
5月27日			5/27	E-07			1.5E-05	0.0	0.3	西門		
5月28日			5/28	E-06			9.0E-06	0.3	0.2	西門		
5月29日			5/29	E-06			7.5E-06	0.3	0.1	西門		
5月30日			5/30	E-06			2.7E-05	0.1	0.1	西門		
5月31日			5/31	E+00			7.6E-06	0.0	0.1	西門		
6月1日			6/1	E+00			7.5E-06	0.0	0.2	西門		
6月2日			6/2	E-06			9.8E-06	0.2	0.3	西門		
6月3日			6/3	E-06			8.1E-06	0.5	0.3	西門		
6月4日			6/4	E-06			7.1E-06	0.9	0.4	西門		
6月5日			6/5	E-06			2.2E-05	0.1	0.4	西門		
6月6日			6/6	E-06			2.6E-05	0.1	0.2	西門		
6月7日			6/7	E-06			2.4E-05	0.1	0.1	西門		
6月8日			6/8	E+00			3.0E-05	0.0	0.0	西門		
6月9日			6/9	E+00			2.3E-05	0.0	0.0	西門		
6月10日			6/10	E+00			1.8E-05	0.0	0.3	西門		
6月11日			6/11	E-06			2.4E-05	0.1	0.3	西門		
6月12日			6/12	E-06			4.0E-06	1.6	0.3	西門		
6月13日			6/13	E+00			1.7E-06	0.0	0.3	西門		
6月14日			6/14	E+00			3.8E-06	0.0	0.4	西門		
6月15日			6/15	E+00			8.3E-06	0.0	0.1	西門		
6月16日			6/16	E-06			5.7E-06	0.3	0.1	西門		
6月17日			6/17	E+00			3.0E-06	0.0	0.1	西門		
6月18日			6/18	E+00			6.2E-06	0.0	0.1	西門		
6月19日			6/19	E+00			1.5E-05	0.0	0.0	西門		
6月20日			6/20	E+00			1.0E-05	0.0	0.0	西門		
6月21日			6/21	E-07			5.7E-06	0.2	0.0	西門		
6月22日			6/22	E+00			9.5E-06	0.0	0.0	西門		
6月23日			6/23	E+00			4.3E-06	0.0	0.0	西門		
6月24日			6/24	E+00			3.2E-06	0.0	0.0	西門		
6月25日			6/25	E+00			1.2E-05	0.0	0.0	西門		
6月26日			6/26	E+00			3.4E-06	0.0	0.0	西門		
6月27日			6/27	E+00			1.9E-05	0.0	0.0	西門		
6月28日			6/28	E+00			3.2E-06	0.0	0.0	西門		
6月29日			6/29	E-06			9.3E-06	0.2	0.1	正門		Main gate
6月30日			6/30	E+00			0.0E+00	0.0	0.1	西門		West gate

Ratio of I-131 to Cs-137 using the aerial radioactive material concentrate inside the 1F site for internal exposure dose estimation (data from the website)

Attached table 1-3 Estimation method for additional intake

In order to eliminate the portion overestimated due to body contamination at initial WBC measurement, difference of counting efficiency for localization to the thyroid gland (characteristic of whole body WBC (NaI)) and iodine correction, data of overestimation has been rejected and more accurate measurement data has been adopted for those who have been evaluated multiple times.

However, considering that overestimation like the above is decreasing as the radioactive material concentration in the work environment decreases, and in order to regularly evaluate internal exposure dose, it is necessary to utilize data from the 2nd measurement and onward.

Therefore, except when meeting the below [rejection standards], the data from the 2nd measurement and onward will evaluate the amount of additional intake after the previous measurement, and the amount of additional intake will be the dose for the 2nd measurement and onward. The estimation method for additional intake is as shown in [Estimation method for additional intake].

[Rejection guidelines]

1.Situations in which influence from body contamination is suspected

2.Situations in which the evaluated value is suspected to be excess due to the difference of counting efficiency for localization to the thyroid gland in the whole body WBC (NaI) measurement

3.Situations in which overestimation is suspected in the WBC (PL) + NaI survey meter measurement

4.Situations in which overestimation is suspected due to iodine correction

[Estimation method for additional intake]

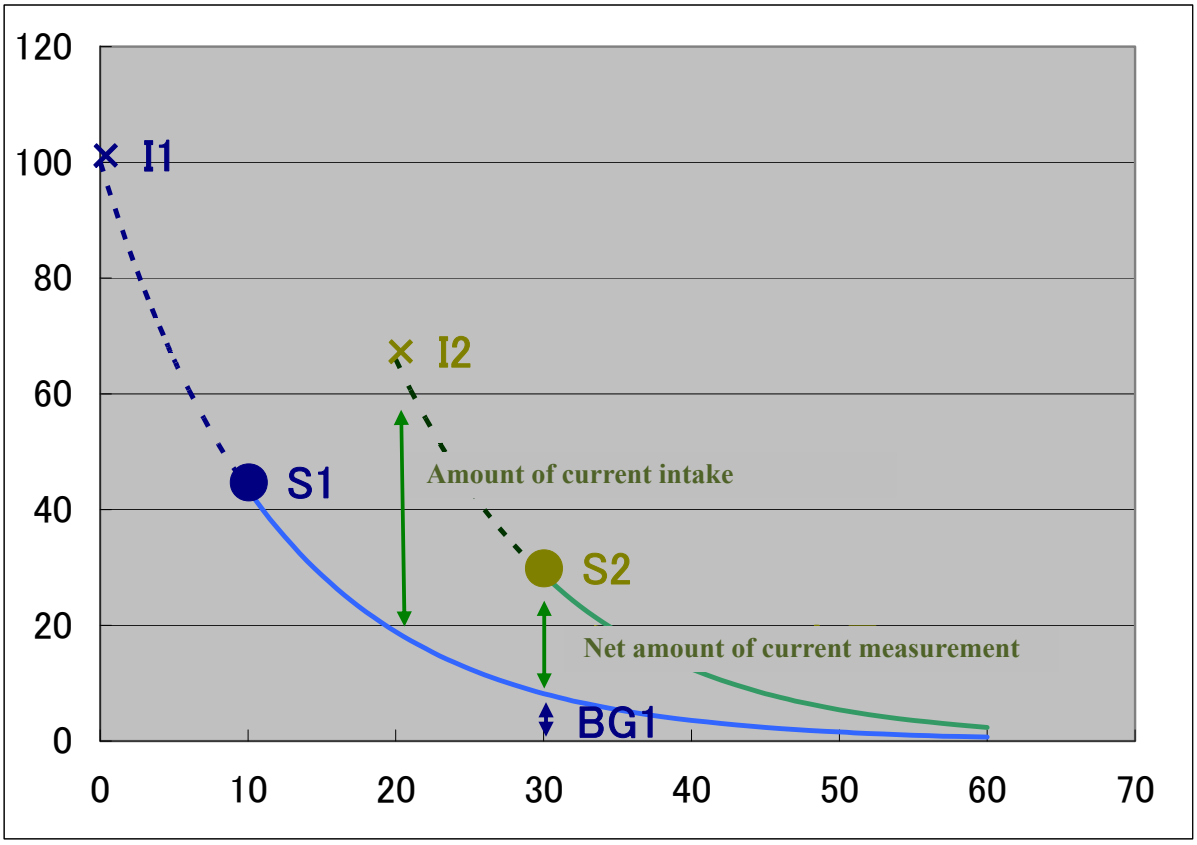


Figure. Estimation method for additional intake

① Attenuate the previously measured value (S1) to the current measurement point (S2) by the residual percentage for each nuclide to derive the residue (BG1) from the previously measured value.

② Subtract the residue (BG1) from the previously measured value from the currently measured value (S2) to set the net amount of current measurement (S2-BG1).

③ The current intake day (for the 2nd measurement and onward) is the day halfway between the previous measurement and current measurement.

④ Divide the net amount of current measurement (S2-BG1) by the residual percentage from the I2 point to S2 point to rebate the current intake day and set the current amount of intake.

⑤ Multiply the current amount of intake by the dose equivalent constant to derive the current dose (additional intake).

Attachment 1-4　Estimation of the intake amount of I-131 based on individual monitoring data of the subjects with significant detection of both I-131 and Cs-137

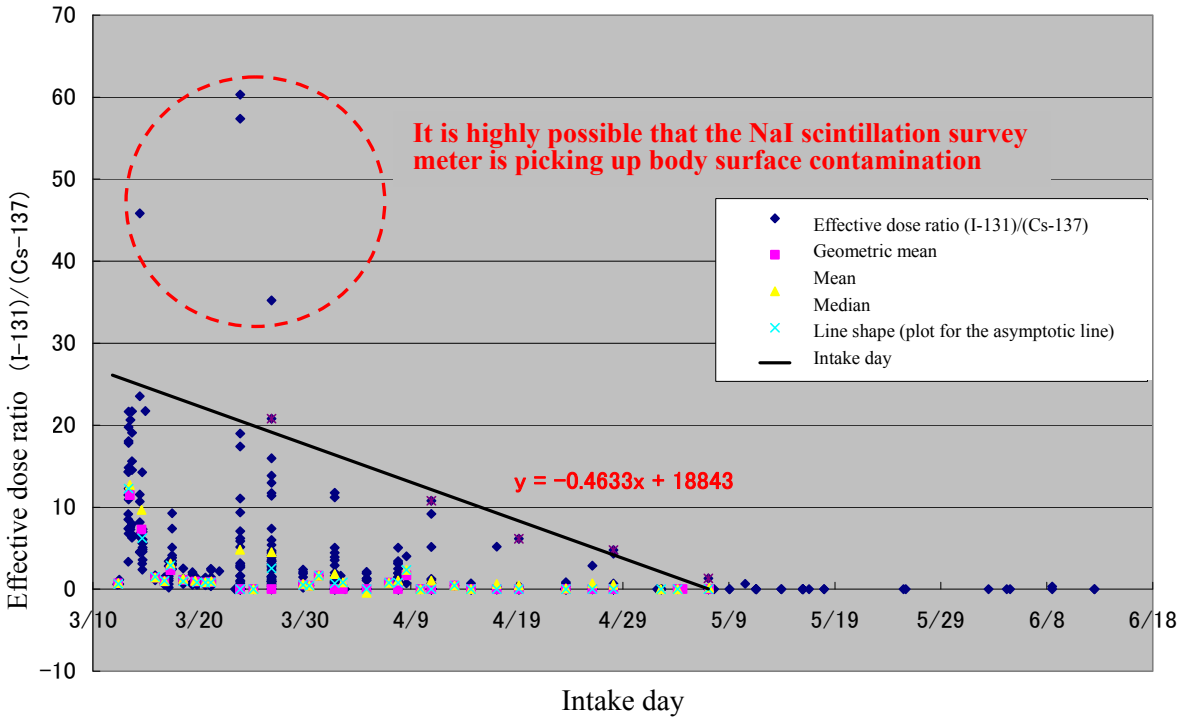


Figure. Relationship between the intake date and effective dose ratio (I-131/Cs-137)

The above figure shows the relationship between the assumed intake date (see Table on Attachment 1) and the effective dose ratio of I-131 to Cs-137. Dose estimations for subjects with no significant detection of I-131 were performed using this relationship as follows.

1. The data (in the figure) were obtained from about 500 workers of TEPCO Kashiwazaki-Kariwa NPS (KK) who were dispatched to 1F, These workers received internal dose measurements at KK after they returned,
2. WBC(Pl) and NaI scintillation survey meter (for thyroid measurements) were used in the measurements at KK.
3. Measurements were conducted 1 to 3 times within 1 month after leaving 1F, and the data which were expected to have small influence of body surface contamination were selected.
4. Measurement with NaI scintillation survey meter was conducted within several days after the workers left 1F. (approx. 2 days later on average).

Based on the above, the effective dose of Cs-137 derived from the WBC (PL) measurement result and the effective dose of I-131 derived from the NaI survey meter measurement result were appropriately measured and estimated.

A conservative correction line was derived using the samples excluding the 4 samples with possibility of contamination from their data.

As shown in the figure, the upper limit of the effective dose ratio (as a function of the intake date) was derived from the data. This limit was used for internal dose estimations of the subjects without significant detection of I-131 in their thyroid measurements.