FUKUSHIMA
Nuclear Accident Veryfication:

Were the exposure levels of Childhood actually Low?

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Increases in Childhood Thyroid Carcinoma Caused by the Fukushima Nuclear Accident

----Verification: Were the exposure levels of Fukushima residents actually low ? ----

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(1) Introduction

As of March 2018, we are now in the eighth year after the Fukushima Nuclear Accident. According to the Investigating and Discussion Committee for Prefectural Residents' Health in Fukushima Prefecture, as of December 2017, among 380,000 children who have received a diagnostic test and whose age was 18 or younger at the time of the nuclear accident, 196 were found to have childhood thyroid carcinoma in Fukushima Prefecture. Regarding the reason for this, the Investigating and Discussion Committee for Prefectural Residents' Health, medical professionals, and academic societies concluded that there was a low probability of an influence by radioactivity from the nuclear accident, although they admit to increases in childhood thyroid carcinoma. They also point out that the possible reasons include (1) detecting latent carcinoma by overdiagnosis and (2) far lower doses of radiation exposure in children of Fukushima compared to the victims of the Chernobyl nuclear accident, where the reason for childhood thyroid carcinoma was determined to be the influence of radioactive contamination. Here, we will investigate whether the thyroid exposure doses in children in Fukushima were actually low.

(2) Amount of iodine-131 released (herein after referred to as I-131)

Although there are various estimates and assessments regarding the amount of I-131 released, to which thyroid carcinoma is attributed (Table 2), we use the data from a report published by the Tokyo Electric Power Company (TEPCO) in May 2012 (Table 1). The whole amount of I-131 released is 473 PBq, while the total amount during the two days of March 15 and 16, is 217 PBq, which accounts for 46% of the entire released amount. The amount of I-131 is 14 times greater than that of the total of cesium (Cs). Note: PBq (petabecquerel) = 10^{15} Bq.

Table 1 Released Amounts of Radioactivity (Published by TEPCO: Calculated Based on May 2012 Data)

Date	I-131	Cs134	Cs137	Date	I-131	Cs134	Cs137
March 12	7.73	0.141	0.106	March 22	0.7	0.025	0.017
March 13	5.012	0.095	0.063	March 23	6.5	0.218	0.213
March 14	48.76	1.031	0.92	March 24	3	0.1	0.1
March 15	110.32	2.029	9.783	March 25	10.88	0.656	0.445
March 16	106.70	2.156	2.113	March 26	0.2	0.01	0.009
March 17	40.033	1.001	0.801	March 27	0.2	0.01	0.009
March 18	22.28	0.777	0.558	March 28	20.779	1.053	0.938
March 19	37.17	2.91	0.734	March 29	9.299	0.828	0.586
March 20	34.8	0.914	0.777	March 30	0.04	0.003	0.002
March 21	8.23	0.319	0.177	March 31	0.04	0.004	0.003
Unit: PBq (petabecquerel) = 10^{15} Bq				Total	472.673	14.279	18.353

Figure 1 Change Over Time of Iodine-131 Released from the Fukushima Daiichi Nuclear Power Station (Prepared Based on Table 1)

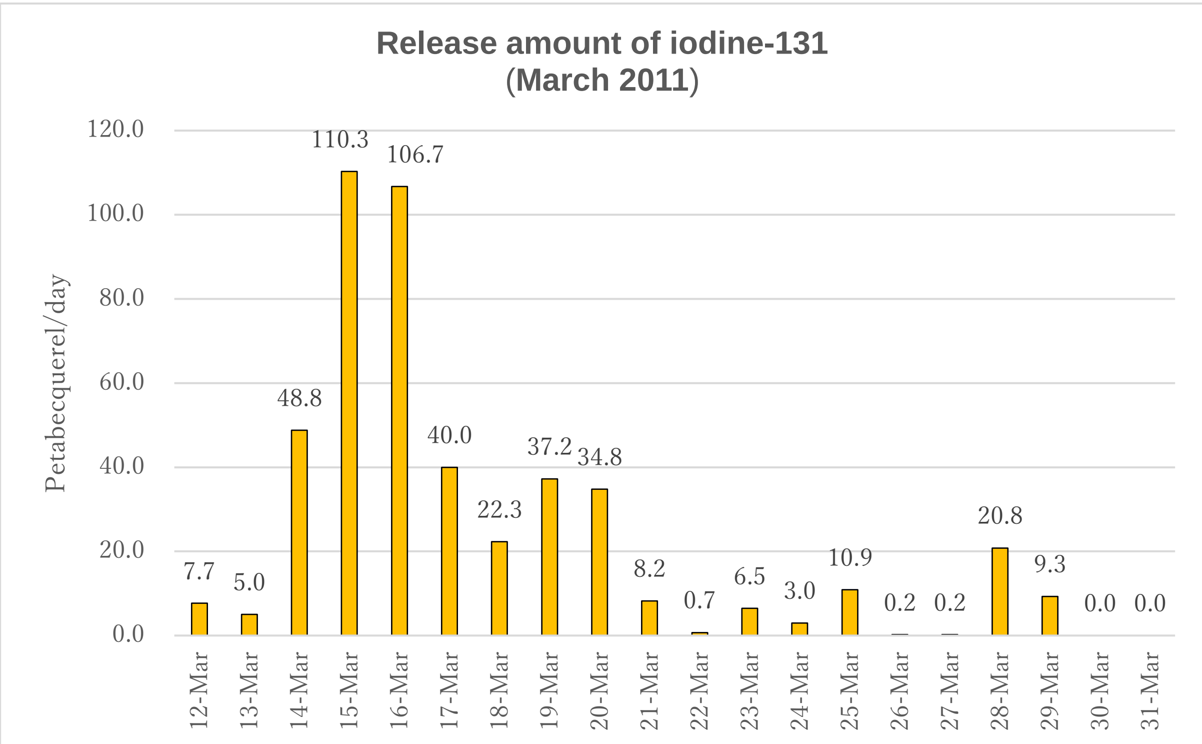


Table 2 Released Amount of Radioactivity into the Atmosphere Due to the Fukushima Nuclear Accident and Chernobyl Nuclear Accident (unit: PBq)

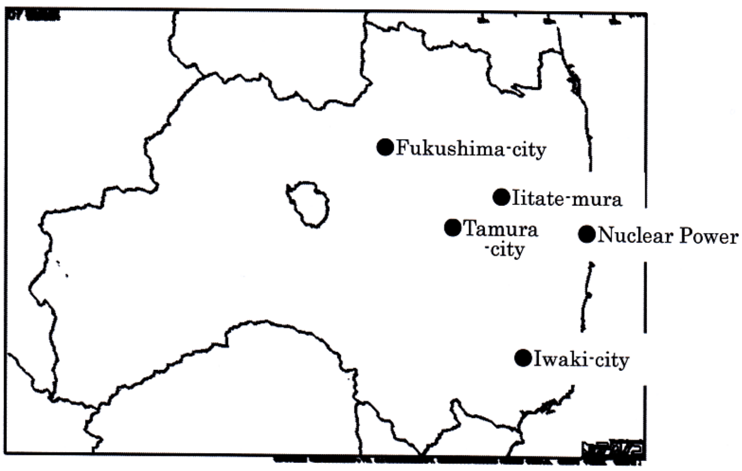
	I-131	Cs137	Cs134	Reference
Chernobyl	- 1,760	- 85	- 47	UNSCEAR Report (2008) (1)
	1,800	85		IAEA Report (2005) (2)
	270	37	18.5	Nuclear Safety Commission (May 28, 1987) (3)
Fukushima	160	15	18	Nuclear and Industrial Safety Agency (October 20, 2011) (4)
	473	18	14	TEPCO Report (May 2012) (5)
	100-500	7-20		UNSCEAR Report (2013 and 2016) (6)

Many arguments adopted data from the United Nations Scientific Committee on the Effects of Atomic Radiation (UNSCEAR) Report to date, which is the basis for the claim that released amounts and contamination levels of radioactivity by the Fukushima Nuclear Accident are ten times lower than those in Chernobyl. However, we should bear in mind that these data are not absolute with a significantly wide margin of error for released amounts of radioactivity because it is based on various assumptions.

(3) I-131 flying leeward and exposure

In Chernobyl, the total radioactivity released from the nuclear power plant located inland caused radiation exposure. In the case of the Fukushima Daiichi Nuclear Power Station, the radioactivity released was highly likely to transfer to the Pacific Ocean because the station is located along the coast, and the accident occurred in early spring on March 12 when the winds often blow from the continent to the Pacific Orcean. Basis on the data from the Japan Mortgage Association, winds blow from the northwest and north-northwest in the direction of the Pacific Ocean in Fukushima Prefecture during this season.

Figure2. Map of Fukushima Prefecture.



In that case, what was the actual direction of the winds at the time of the Fukushima Daiichi nuclear accident? Although most observation stations located along the coast were lost because of the earthquakes, tsunami, and power failures, some small amount of data from the Japan Mortgage Association about wind directions on March 15 and 16 remained in some areas, including Iitate-mura just 40 km northwest, Tamura City 45 km west, and Onahama City, located 50 km southwest in the southern part of the prefecture, each some distance from the nuclear power plant.

The wind roses based on these data are shown in Figure 3

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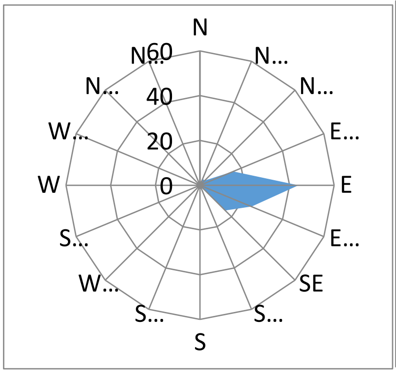
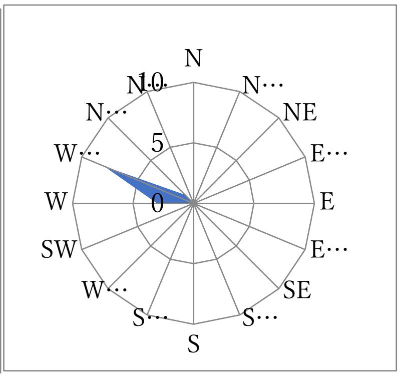
Figure 3 Wind Roses at the Time of Accident



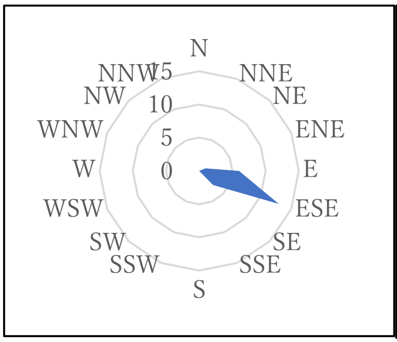
Iitate-mura

March 15, 2011(1a.m.~11. p.m.)



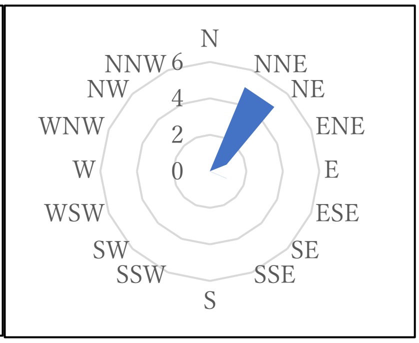
Iitate-mura

March 16, 2011 (1 a.m.~12 p.m.)



Funehiki-machi, Tamura City

March 15, 2011 (1 a.m. to 11 p.m.)



Onahama City

March 15, 2011 (1 a.m. to 12 a.m.)

From the results of our chronological review of the data of the frequencies of wind direction, we found the following: the most frequent wind direction was northeast to north-northeast in Onahama from 12 a.m. to 12 p.m. on March 15, where the radioactive plume moved to Iwaki City (a densely inhabited district with a population of 340,000 people) located southwest to south-southwest, or to other areas; the most frequent wind direction was almost east to east-southeast in Iitate-mura (40 km northwest of the nuclear power plant) in Fukushima Prefecture on the afternoon of March 15, where most of the radioactive plume released during this period of time moved to Iitate-mura and Fukushima City located just past Iitate-mura, (63 km northwest away from the plant). A similar result was obtained for Funahiki-machi in Tamura City (45 km west of the nuclear power plant) to the west of which Koriyama City (a big city with a population of 350,000 people) is located. On March 16, northwest to north-northwest winds blowing throughout the day made the radioactive plume float over the Pacific Ocean.

Accordingly, approximately a quarter of the total I-131 released moved to the inland areas of Fukushima, including a big city, on March 15. ***Archives of Weather Data Around the Fukushima Daiichi Nuclear Power Plant: March 11 to 25, 2011/Wind Direction and Wind Velocity (Mesoscale Model)*** consists of wind directions and wind velocity at the time of the accident visualized by time (http://agora.ex.nii.ac.jp/earthquake/201103-eastjapan/weather/data/wind-20110311/). This is a model where wind direction and wind velocity around the nuclear power plant at the time of the accident are visualized, which support the above-mentioned analysis (Figure 4).

Consequently, the air dose rates significantly increase to as high as 20 to 25 µSv per hour within Fukushima City and Iwaki City (7). Graphs obtained by combining the data of the time and amount of released I-131, published by TEPCO, with the results of measurements of air dose rates at corresponding time points in Fukushima City and Iwaki City are shown in figures 4 and 5, respectively. As mentioned above, at the time when a high level of radioactivity was released from the nuclear power plant on March 15, the wind was blowing towards the inland area, so it was inevitable that many residents would be exposed to radiation. Regarding I-131, most of the amount (25% of the total amount released) released on March 15 flowed to inland, which exposed the residents to radiation.

Incidentally, regarding radioactive cesium, 36% of the total amount released, 11.8PBq (a total of 32.7 PBq: Cs134 plus Cs137) flowed inland on March 15, based on calculations from Table 1 (released by TEPCO). The theory, which has been said, that 10% of the released radioactivity from the Fukushima nuclear accident flowed inland while 90% moved over the Pacific Ocean is not true. To be precise, at least 24% of the released amount of I-131 and 36% of the total of Cs134 and Cs137 are believed to have flowed inland.

Figure4　An Example of Mesoscale Model for Wind Directions Around the Nuclear Power Plant

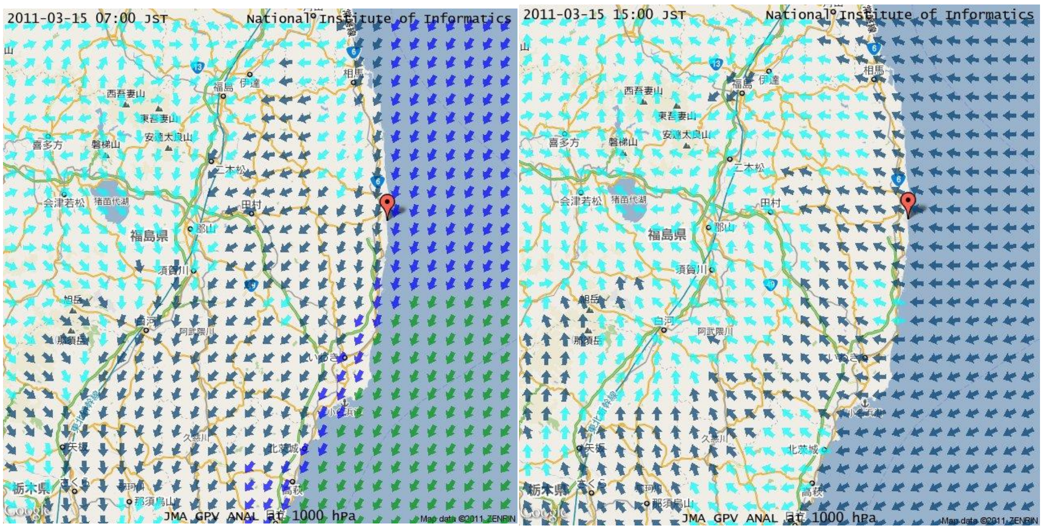


Figure5. Release Amount of I-131 and Air Dose Rates Within Fukushima City (March 2011)

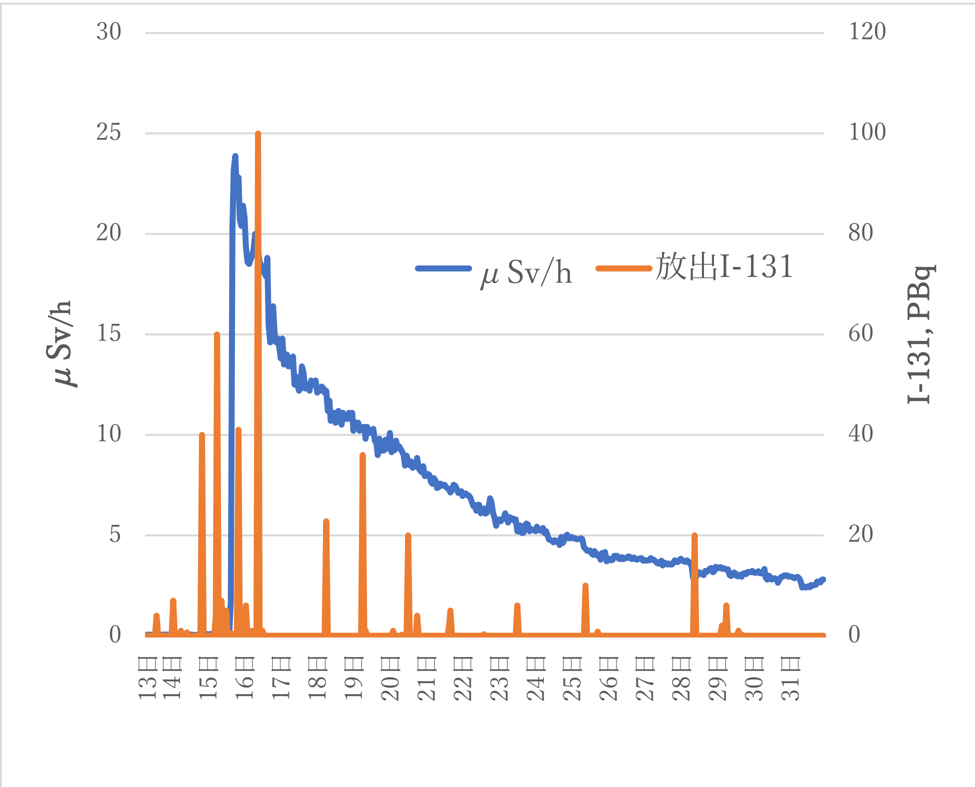
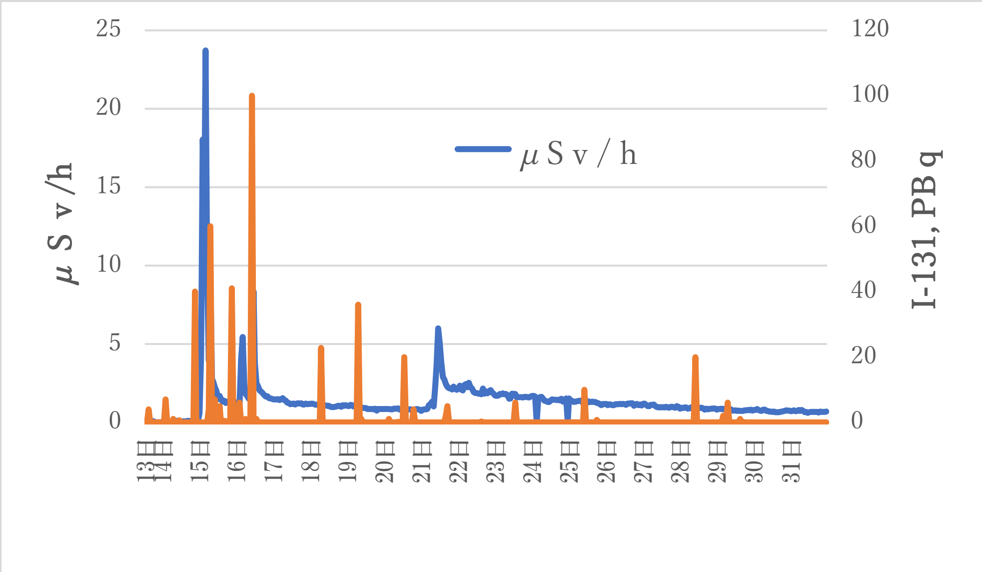


Figure 6. Release Amount of I-131 and Air Dose Rates Within Iwaki City (March 2011)

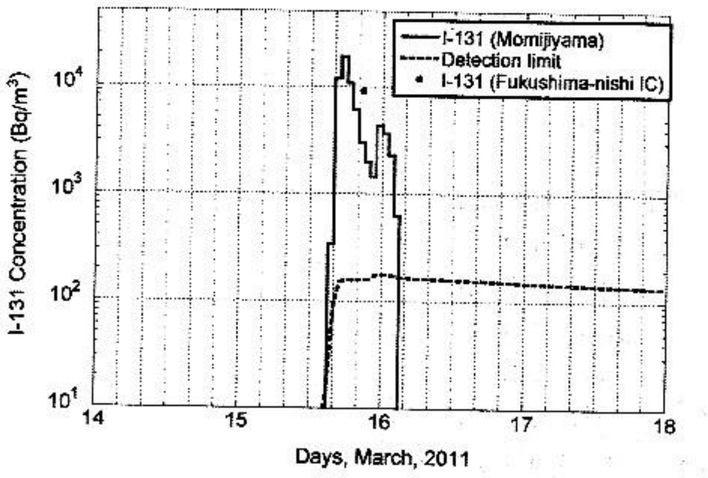


The government issued evacuation orders for some residents living within a 20-kilometer radius of the plant, including Okuma-machi, Futaba-machi, Tomioka-machi, and Namie-machi at 6:25 p.m. on March 12. However, it was not until April 11 that the outer areas within a 20- to 30-kilometer radius of the plant, including Katsurao-mura, Namie-machi, Iitate-mura, Kawamata-machi and Minamisouma City (partly), were designated as part of the planned evacuation zone (area with a possible 20 mSv or more exposure per year) by the officials and evacuation was called for. Before then, the amount of iodine-131 released accounted for 89% of the total. The evacuation orders were not issued for big cities outside the 30-kilometer circle, including Fukushima City, Koriyama City and Iwaki City. Accordingly, before March 20, when a large amount of radioactivity flowed inland, most of the residents were exposed to radioactive iodine and cesium, except for those who voluntarily evacuated in the early stages.

(4) I-131 concentration in the atmosphere

How was I-131 released from the nuclear power plant spread into the air and how were the levels in the atmosphere in Fukushima Prefecture? There are no specific values measured in Fukushima Prefecture from March 12 to 18 just after the accident, when the highest levels of I-131 were released, except for a measurement by TEPCO around the nuclear power plant premises. There are only three measurement results: the actual measurements made by the Japan Atomic Energy Agency (JAEA) in Tokai-mura, Ibaraki Prefecture, only 110 km south of the Fukushima Daiichi Nuclear Power Plant at the monitoring posts around the institute starting from just after the accident (8), the measurements made by the High Energy Accelerator Research Organization (KEK) located in Tsukuba City, Ibaraki Prefecture, starting from March 15 within the compound of the National Institute for Environmental Studies (9), and the observation results on or after March 12 made by the CTBT Radionuclide Monitoring Station established in Takasaki City in Gunma Prefecture (217 km away from the Nuclear Power Plant) by the Center for the Promotion of Disarmament and Non-Proliferation, belonging to the private organization, the Japan Institute of International Affairs, in order to monitor nuclear testing (10). According to JAEA, the air dose rates in Tokai-mura rose sharply from 5 a.m. to 8 a.m. on March 15 when northeast to north-northeast winds blew to a maximum of 4 μSv/h from a normal range of 0.03 to 0.04 μSv/h. The concentrations of I-131 in the atmosphere, which were collected at the same time, showed a maximum level of 1,600 Bq/m3 from 6 a.m. to 9 a.m. The I-131 was composed of volatile and particulate elements in an almost half-and-half ratio (8).

Figure 7. Change in I-131 Concentrations in the Atmosphere of Momiji-Daira in Fukushima City Around March 15 (Hirayama et al.: 11)



In addition, based on an analysis of samples collected from 14:39 p.m. to 17:34 p.m. on March 15 using a dust sampler performed by KEK, the I-131 concentration was 3.2×10-5 Bq/cm3 (=32 Bq/m3)(9). In an observation by the CTBT Radionuclide Monitoring Station, the air collected from March 15 to 16 showed a measurement of 14,680,552 μBq/m3 of I-131 (= 14.68 Bq/m^3) (10).

Besides this, in research by Hirayama from KEK et al., the I-131 concentration in the atmosphere in Momiji-daira in Fukushima City (61.3 km northwest of the nuclear power plant) was estimated with a model calculation based on a spectral analysis using radiation dose measurements that Fukushima Prefecture had performed since before the accident at multiple monitoring posts. As a result, the peak concentration of the I-131 was reached between 5 p.m. and 6 p.m. on March 15 with a maximum 19,100 Bq/m3, and the mean was 3,650 Bq/m3. Concentrations in the atmosphere showing over several thousand becquerels per cubic meter were maintained until around 4 a.m. on March 16 (11). A graph showing, I-131 concentrations in the atmosphere of Momiji-daira in Fukushima City is cited from the paper written by Hirayama (Figure7).

According to Hirayama et al., the mean concentration × duration (=integral time concentration in the atmosphere) of the atmosphere of Momiji-daira in Fukushima City from March 15 to 16 was 65,700 (Bq h/m3). If this figure is correct, in Fukushima City, the I-131 dose inhaled by adults (breathing capacity per day, 20 m3) was 54,750 Bq per day, and the dose inhaled by elementary school students (breathing capacity per day, 10 m3) was 27,375 Bq.

In this paper, the integral time concentration in the atmosphere measured in Hirono-machi, Futaba-gun, (21.4 km south of the nuclear power plant) during the five days of March 12 to 16 was calculated to be 137,000 Bq h/m3. In Hirono-machi, I-131 dose inhaled by adults (breathing capacity per day, 20 m3) was 114,000 Bq per day, and the does inhaled by elementary school students (breathing capacity per day, 10 m3) was 57,000 Bq.

The officials ordered emergency evacuation preparation zones for Hirono-machi, Tamura City, Kawauchi-mura, Naraha-machi, and Odakaku of Minamisouma City (20 to 30 km from the nuclear power plant) on April 22, 2011. Thus, most of the residents were exposed to high levels of radioactive I-131 on or after March 15, except for those who voluntarily evacuated during the early stages. In particular, Namie-machi in Futaba-gun is spread northwest of the nuclear power plant. It was found later that this area was included within the severely contaminated areas where the radioactive plume passed through. However, the residents evacuated to Tushima-district in Namie-machi 29 km northwest of the nuclear power plant just after the accident. The explosion of reactor unit 3 of the Daiichi nuclear power plant drove them to make the decision to evacuate to Nihonmatsu City at 10 a.m. on the 15th. Until then, about 8,000 residents stayed in Tushima-district. The explosion of reactor unit 3 drove these residents to begin to evacuate from the morning of March 15 to the morning of March 16, during which large amounts of radioactivity were released from the nuclear power plant and even the radioactive plumes spread in the northwest direction. The residents in this region should have ingested large amounts of I-131 into the body incomparable with the amounts in Fukushima City or Hirono-machi. Actually, the air dose rate measured in Tushima-district in Namie-machi in March 16 was as high as 58.5 μSv/h. A great responsibility was laid upon the Japanese government because they did not measure the concentrations in the atmosphere despite knowing of this situation in advance by predictive investigations with SPEEDI and because they did not inform residents of the predictive investigations results.

It was not until radioactivity measurement started with dust sampling by both the Ministry of Education, Culture, Sports, Science and Technology (MEXT) (on or after March 18) and Fukushima Prefecture (on or after March 19) that I-131 or other radioactivity in the atmosphere were continuously measured (12). Based on measurements performed by MEXT, the following I-131 concentrations were observed: 4,900 Bq/m3 on March 20 in Katsurao-mura of Futaba-gun, 3,700 to 5,600 Bq/m3 on March 21 in Hirono-machi of Futaba-gun, 440 to 290 Bq/m3 on March 25 in Iitate-mura and 1,000 Bq/m3 on March 20 in Namie-machi. Such values should have been much higher than those above if measured from March 15 to 16, when the largest amounts of I-131 were released from the nuclear power plant and the winds blew inland. Other than those measurements, there are no reliable measurement values because of a large amount of errors caused by models and assumption used for calculation, although the concentrations of I-131 are estimated based on the concentrations of I-131, CS134, and CS137 deposited on the ground surface in multiple studies.

(5) **Examination of radiation exposure in the thyroid gland**

From May to June in 1986, soon after the Chernobyl nuclear accident (April, 26, 1986), the government of the Republic of Ukraine measured radioactive iodine in the thyroid gland in 150,000 or more residents, including 130,000 children, in three provinces (Kiev, Zhytomyr, and Chernigov) located close to the nuclear power plant followed by measurements in children in all provinces (13). A partial extract from this data is shown in Table 3.

Table 3 Results of the Thyroid Examination Conducted by the Government of the Republic of Ukraine Just After the Chernobyl Nuclear Accident (13)

	Mean thyroid exposure dose by age (mGy: milli gray = mSv)				
Province name	<7 Years of Age	7-14 Years of Age	15-18 Years of Age	>18 Years of Age	Overall Mean
Vinnitsa	37	13	9.8	9.2	12
Zhytomyr	231	87	67	60	81
Kiev	202	75	58	53	71
Odessite	15	5.2	3.8	3.7	5.1
Chernigov	151	55	43	37	50
Total of Ukraine	55	20	15	14	19

* Only some of 23 provinces are reproduced.

Nothing was more surprising than the fact that the amounts of I-131 in the thyroid gland were measured in as many as 130,000 children within several weeks after the incident. Given that the measurements were made within one month after the accident, the amounts of I-131, of which the half-life is 8 days, could be easily measured. In contrast, how was the aftermath of the Fukushima nuclear accident handled in Japan?

In Japan, only two sets of actual measurements of I-131 in the thyroid gland are available. In the first measurement conducted by Professor Tokonami, et al. from Hirosaki University, I-131 in the thyroid gland was measured in a total of 62 people consisting of 17 residents in Namie-machi of Fukushima Prefecture and 45 evacuees from Minamisouma City to Fukushima City from April 11 to 16 one month after the accident (14). In addition, Professor Tokonami, et al. measured the radioactivity in 2,393 evacuees from Namie-machi from June, at least three months after the accident, to August 2011 by using a whole-body counter to estimate the absorbed amounts of I-131 just after the accident based on the ratio of I-131 to Cs134 by which they estimated the thyroid equivalent dose and reported the results (15).

In the other measurement, the Local Nuclear Emergency Response Headquarters performed thyroid examinations at the request of the Nuclear Safety Commission in a total of 1,080 children aged 0 to 15, consisting of 134 in Iwaki City of Fukushima Prefecture from March 26 to 27, 631 in Kawamata-machi of Fukushima Prefecture from March 28 to 30, and 315 in Iitate-mura of Fukushima Prefecture from March 29 to 30 (16).

(5-1) Analysis of I-131 in the thyroid gland by Professor Tokonami et al.

Professor Tokonami, et al. investigated the gamma-ray spectrum by applying a 3-inch x 3-inch NaI (Tl) scintillation spectrometer (JSM-112: Hitachi Aloka) to the neck of subjects. Based on the obtained values, an amount of I-131 expressed in becquerels and the thyroid equivalent dose were calculated. Residents in Namie-machi evacuated under the evacuation order issued on March 12 from the area located along the coast to Tsushima-district located to the northwest of the area. As mentioned above, the radioactive plumes that were released from the nuclear power plant starting from around 11 a.m. on March 15 should have flowed with the southeast to south-southeast winds to Tsushima-district. However, Professor Tokonami performed measurements one month later in 17 Namie-machi residents, among them only 7 showed measurements not lower than the limit of detection (LOD). Among a total of 45 people evacuated from Minamisouma City to Fukushima City, 39 showed measurements above the LOD, accounting for 74% of the total of 62 subjects. On the hypotheses that all residents in Namie-machi and Minamisouma City had acute inhalation from inhalation, 30% of the dose was absorbed into the thyroid gland; the residents were breathing for 4 hours, so the intake dose of I-131 and the thyroid equivalent dose were calculated. The obtained results are shown in Table 4.

Table 4 Results of the Examination of Radiation Exposure in The Thyroid Gland Caused by the Fukushima Nuclear Accident by Professor Tokonami, et al. From Hirosaki University (15)

Age	Number of People	I-131 Accumulation (KBq)	Thyroid Equivalent Dose (mSv, on the Hypothesis of All Being by Breathing)
0-9	5	ND-0.017	ND-21
10-19	3	0.09-0.54	3.8-23
20-29	9	ND-0.59	ND-16
30-39	6	ND-0.17	ND-4.4
40-49	4	ND-1.5	ND-33
50-59	10	ND-1.1	ND-31
60-69	12	ND-0.20	ND-5.3
70-79	3	0.090-1.5	2.3-31
≥80	2	ND-0.70	ND-19
Unknown	8	ND-1.4	ND-28
Mean		19 years old or younger (4.2 mSv); adult (3.5 mSv)	
Maximum		19 years old or younger (23 mSv); adult (33 mSv)	

(Note by Kawata) ND represents the limit of detection (values of ND and background are not presented).

The maximum level of I-131 concentration in the thyroid gland of 1,500 Bq was observed in one adult. In this paper, Professor Tokonami et al. pointed out the possibility, based on the estimation of I-131 concentrations in the atmosphere in Iitate-mura on the afternoon of March 15, that this subject may have inhaled I-131 at a maximum level of 85,000 Bq and that children 1 to 5 years of age may have been exposed to I-131 at a maximum level of 63 mSv, which is higher than the actual measurement of 21 mSv.

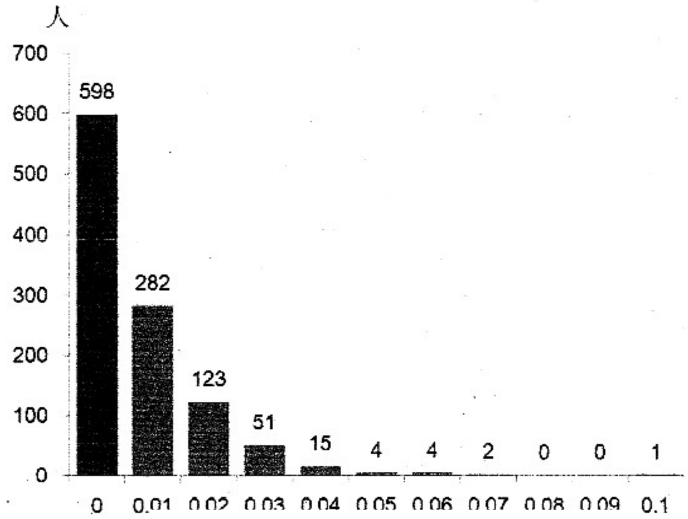
The breathing time was assumed to be four hours because, although air dose rates suddenly rose after the arrival of the radioactive plume at Namie-machi around 1 p.m. on March 15, there was no absorption through inhalation because I-131 was deposited on the ground due to rain starting from around 5 p.m. in the evening, the author explains. However, this hypothesis is unreasonable. For example, approximately half of the I-131 coming in particulate form then led to deposition by rain while the remaining half thereof was in gaseous form resulting in limited absorption by rain. In addition, most of the radioactivity within the plume was unlikely to be deposited on the ground because, based on data from the Japan Mortgage Association, it was raining lightly with a precipitation rate of 0 to 1.5 mm per hour from March 15 to 16 in Iitate-mura adjacent to Tsushima-district. If most of the I-131 had been deposited on the ground, it would not have arrived at Fukushima City, which is located just past Iitate-mura, which is factually inaccurate. Furthermore, the author also explains that many residents were evacuated from Tsushima-district by the time the plume had arrived after the evacuation order was given on March 15, possibly resulting in prevention of absorbing contaminated air. This hypothesis is also factually inaccurate. After the Namie-machi office decided to issue the evacuation order from Tsushima-district to Nihonmatsu City in the early morning of March 15, residents evacuated starting from 10 a.m. and finishing in the evening. Given the air dose rate of 58.5 μSv per hour observed on March 16 in Tsushima-district, the value on the previous day of March 15 should have been much higher. In this connection, even though Fukushima City received rain on March 15 and 16, as mentioned above, a large amount of I-131 in the atmosphere was observed even in the Fukushima City. In this way, given the fact that the measurement of thyroid exposure dose one month after the accident by Professor Tokonami et al. was based on various hypotheses, the amounts of actual exposure doses could have been greater.

(5-2) Analysis of I-131 in the thyroid gland and background error

A more significant issue is the background radiation (Bkg) at the time of measurement. The government noticed on March 25, 2011 that the screening level at the time of measurement of radiation exposure in the thyroid gland was 0.2 μSv/h (17). This was based on a model test using a phantom, where if an actual measurement of radiation exposure in the thyroid gland was 0.2 μSv/h, the dose would correspond to I-131 accumulation in the thyroid gland of 4,400 Bq and to thyroid exposure of an equivalent dose of 108 mSv in a one-year-old infant, leading to the limitation of the Bkg in measurement environments to not more than this value. Although this hypothesis itself has a large problem, here we will discuss problems only regarding Bkg. On or after March 15 when I-131 came in, air dose rates as high as 10 to 100 times the 0.2 μSv/h were observed, needless to say within Fukushima Prefecture, even within the peripheral prefectures. In this environment, it should be very difficult to secure a place in which Bkg was 0.2 μSv/h or lower. Given a Bkg of 0.2 μSv/h and an actual measurement of 0.22 μSv/h, it was evaluated that the net value was 0.02 μSv/h, an I-131 accumulation in the thyroid gland of a one-year-old infant was 440 Bq, and an equivalent dose of exposure was 10 mSv. It is highly unlikely that these measurements were performed at high accuracy in this environment where air dose rates ranged from several micro- to several tens of micro sieverts per hour. The higher the Bkg, the bigger the subtracted value and the lower the net value. As a result, exposure doses were underestimated. Furthermore, a net value of measurements becomes inaccurate with large errors. The results of measurements performed by the Local Nuclear

Emergency Response Headquarters were actually not clear. These measurement results have been reported on May 12, 2011, under the name of the Secretariat of Nuclear Safety Commission (16, 18). A graph representing the results is shown in Figure 8.

Figure 8. Result of Measurement in the Thyroid Gland in a Total of 1,080 Children from Kawamata-Machi, Iitate-Mura and Iwaki City (18)



Net value of survey meter (μSvh^{-1})

In a total of 1,080 children aged 15 years or younger consisting of 134 children measured at the health center of Iwaki City, 631 children measured at the community center of Kawamata-machi and 315 children measured at the community center of Iitate-mura, measurement results are thought to be as follows: a maximum dose of 0.1 μSv/h was reported in one child, 0 μSv/h was reported in 598 children (55.4%), and children with 0.04 μSv/h or lower accounted for 99% with no children having doses above the screening level (0.2 μSv/h = 100 mSv as thyroid equivalent dose of a one-year-old infant). This result was shown in the 2012 Project for Investigation on Impact of Nuclear Power Plant Disaster—Investigation of Internal Exposure Due to Short Half-life Such as Iodine at the Early Stage of the Accident—Accomplishment Report (18) and a paper written by E Kim et al. from the National Institute of Radiological Sciences (19). According to a calculation made by the author or others, the mean thyroid equivalent dose was 7.3 mSv in 631 people in Kawamata-machi, 15.9 mSv in 134 people in Iwaki City, and 14.7 mSv in 315 people in Iitate-mura. Among them, a child 4 years of age was thought to show the maximum 0.1 μSv/h, corresponding to 35 mSv (Figure8).

However, as mentioned above, it is clear that the measurement of background radiation levels (Bkg) has a large error. Materials showing the actual measurement conditions are attached to the Investigation Progress of Radiation Exposure in the Thyroid Gland of Children: 20 within the Report by the Secretariat of the Nuclear Safety Commission issued on September 13, 2012. According to the materials, in the measurements in Yamakiya-district in Kawamata-machi on March 24, the Bkg was 2.4 to 2.9 μSv per hour, and the measured net value, which was obtained by subtracted this measurement, was around 0.1 μSv/h with many negative values observed. Needless to say, the data from measurements on 66 people on this day, including those performed at the health center of Kawamata-machi, were not used. In addition, measurements subsequently performed with 1,080 people on or after March 26 also showed Bkg values ranging from 0.1 to 0.2 μSv/h and net values ranging from 0 to 0.01 μSv/h in most of the data. These data are far from reliable. For example, when the measured value is 0.21 μSv/h on the assumption that Bkg is 0.2 μSv/h, the following values are obtained by calculation: the net value is 0.01 μSv/h, an I-131 accumulation in a one-year-old infant is 220 Bq, and the thyroid equivalent dose is 5 mSv. Whereas on the assumption that Bkg is at the same level as that before the accident (0.04 μSv/h), a dose rate derived from the I-131 deposition amount in the thyroid gland is calculated to be (0.21-0.04) μSv/h = 0.17 μSv/h and the thyroid equivalent dose is 0.17÷0.2×100=85 mSv. As mentioned above, Bkg values can cause a large error in measurements of I-131 deposition amount in the thyroid gland at the devastated areas just after the accident, from which exposure doses were calculated and could have been largely underestimated.

(5-3) Issue of I-131 absorption model (chronic and acute absorption)

The third factor that causes errors is the issue related to the timing of the intake of I-131 and the duration (hours) to thyroid examinations. This issue has the largest impact on the assessment of exposure dose. As mentioned above, the screening level of 0.2 μSv/h defined by the Nuclear Safety Commission was thought to correspond to I-131 accumulation in the thyroid gland of 4,400 Bq and to an equivalent dose of exposure of 108 mSv in the thyroid gland of a one-year-old infant. The basis for this calculation is reported to be as follows: on the hypothesis that a one-year-old infant continued absorbing I-131 (chronic absorption) at a certain level on a daily basis for 12 days starting from March 12 (when the nuclear power plant exploded) to March 24 (when measurements started), the half-life, daily amounts taken into the body, and accumulated amounts in the thyroid gland were taken into account (Attachment 5-2 of Reference 20). However, as already mentioned above several times, the residents absorbed radioactive iodine into their bodies mostly on March 15 due to wind directions. Consequently, the exposure dose should be assessed by using a formula called the single (acute) absorption model, not the chronic absorption model. According to ICRP (Publication 72), in the single absorption model, the radioactivity accumulates in the thyroid gland and reaches a peak one day after absorption into the body, followed by a gradual decrease due to the half-life and excretion from the body in urine. On the assumption of single absorption (1 Bq) on March 15, for a one-year-old infant, the internal residual rate on March 26, when the government started measurements, is 0.0308 Bq and the committed effective dose at this time is 2.338E-06 (Sv/Bq) (=2.338 μSv/Bq). If an actual measured exposure dose is 0.2 μSv/h (4,400 Bq), the committed effective dose is calculated to be 2.338E-06×4400=1.0287E-02 Sv (=10.287 mSv) and the thyroid equivalent dose is calculated to be 257 mSv (the tissue weighting factor for thyroid gland is 0.04). Specifically, the thyroid equivalent dose calculated from values measured 11 days after absorption of I-131 based on a single absorption model is 2.7-fold greater than that based on a chronic absorption model. Table 5 shows the change in the residual dose and the thyroid equivalent dose in the thyroid gland in a one-year-old infant based on a single I-131 absorption model on March 15 on each measurement day from March 26 to 30 for which measurement was performed in 1,080 people by the government.

As mentioned above, the thyroid equivalent dose significantly varies depending on how I-131 is ingested according to the day, method, and timing. In this case, considering that the radioactive plume was scattered inland on March 15, exposure doses should be assessed based on a single absorption model, not on a chronic absorption model, which would lead to a considerable underestimation. Although I have to admit that accurate measurements and assessments of the thyroid gland were difficult in the chaos just after the accident, at a later stage where the truth had come out over time, the exposure of the thyroid gland should have been properly assessed to correct the exposure doses. These measurements are likely to lead to such various underestimations or errors. However, once reports or papers about the measurements are published, the data would be unstoppable without appropriate criticism and be used to publicize that thyroid exposure in children was very low.

Table 5 Change in Time Elapsed from Absorption to Measurement Day in the Thyroid Gland, Residual Rate in the Thyroid Gland, Effective Dose and Equivalent Dose in a One-Year-Old Infant Absorbing Iodine-131 (1 Bq). (Calculated by the Author Based on a Single Absorption Model)

Number of lapsed days from absorption to measurement day		Day 11	Day 12	Day 13	Day 14	Day 15
1 Bq Absorptio	Residual Rate (Bq)	3.08E-02	2.73E-02	2.42E-02	2.15E-02	1.90E-02
	Effective dose (Sv/Bq)	2.338E-06	2.637E-06	2.975E-06	3.349E-06	3.789E-06
	Thyroid equivalent dose (Sv/Bq)	5.845E-05	6.593E-05	7.438E-05	8.373E-05	9.473E-05
Thyroid equivalent dose in a one-year-old infant based on a single absorption model for measured value 0.2 μSv/h (4,400 Bq) (calculated by the author)		257 mSv	290 mSv	327 mSv	368 mSv	417 mSv
Thyroid equivalent dose in a one-year-old infant based on a chronic absorption model for measured value 0.2 μSv/h (4,400 Bq) (Reference 20)			108 mSv			

(5-4) Issue of estimating absorbed I-131 by a whole-body counter

Several reports or papers about thyroid exposure dose are available, most of them estimate I-131 doses in the thyroid gland just after the accident, based on a ratio of Cs137 or Cs134 to I-131 measured by using whole body counters (WB) several months after the accident. In this case, the problem is as follows: Most I-131 taken into the thyroid gland just after the accident was due to absorption of contaminated air on March 15 when the radioactive plume came inland. However, radioactive cesium was measured by using a whole-body counter after a certain period of time had elapsed, and most of the cesium exposure was caused by consuming contaminated foods and water. Thus, the results from estimating accumulated I-131 in the thyroid gland are not replicable because of the complicated interaction among differences between iodine and cesium in the circulation pathway in the body, in the routes and timing of crop contamination, and in the production area of the crops. Assessments of thyroid exposure dose by these reports and papers are thus thought to be far less reliable.

(6) Infant exposure through contaminated breast milk

As the thyroid gland, a tissue where the growth hormone is produced, contains iodine as a component, contamination of breast milk by I-131 could be a major factor in exposure in infants with active growth. Nevertheless, it was not until recent years that a lot of specific research was conducted. I-131 taken into the body is accumulated in the thyroid gland through various pathways. Based on previous studies, approximately 30% of I-131 taken into the body is transported into the thyroid gland, and the remaining is excreted from the body in urine. The method to directly analyze secretions excreted from the body, including breast milk and urine, and in order to investigate radioactivity, such as I-131, Cs134, and Cs137, is called a bioassay. Although some analyses have been performed for Cs137 and Cs134 in breast milk and urine since the Chernobyl nuclear accident, there are few analyses of I-131 in breast milk.

In response to the 2007 recommendation of ICRP (Pub. 103), the Radiation Council of Japan issued a recommendation in January 2011 that, regarding exposure management for women who are occupational radiation workers, countermeasures against radiation exposure for pregnant women, infants, and fetuses should be included in the domestic systems (21). “It can be regarded that exposure of infants through breast milk is indirectly managed by regulating internal exposure in occupational radiation workers. However, investigations into actual conditions about the exposure of infants due to radionuclide transfer through breast milk have not been performed in Japan to date. Investigations into the actual conditions about these issues should, therefore, be performed and considering the results obtained, it is appropriate to discuss the need for development of a system to implement protective measures reflecting our country’s situation for infants during lactation,” this recommendation says. Although the Fukushima Nuclear accident happened just after this recommendation was issued (March 2011), both the Radiation Council and the Nuclear Safety Commission did not take any concrete measures nor did they perform radioactivity measurements in breast milk.

(6-1) Results of measurements of I-131 in breast milk

After the Fukushima nuclear accident, a civic organization called the Network to Examine Breast Milk and Support Mothers and Children (Mother-and-child Support Net: representative, Kikuko Murakami) collected breast milk from mothers living in the Tohoku region for examination. This is a rare action in the world. This civic organization called for the examination of breast milk from the middle of March just after the accident when they recalled that at the time of the Chernobyl nuclear accident, a trace amount of radioactivity was detected in breast milk collected from mothers living in Osaka. A total of nine breast milk samples were collected from March 16 to April 12, in 4 of which I-131 could be detected. (Table 6 and 22).

Table 6 Results of Examinations by Network to Examine Breast Milk and Support Mothers and Children (22)

Name of Lactating Woman	Date of Breast Milk Sample Collection	Date of Examination	Iodine-131 (Bq/Kg) (Limit of Detection)	Place of Residence
A	03/23/11	03/24/11	8.7	Tsukuba City, Ibaraki Prefecture
B	03/23/11	03/24/11	ND	Tsukubamirai City, Ibaraki Prefecture
C	03/23/11	03/24/11	31.8	Moriya City, Ibaraki Prefecture
D	03/29/11	04/04/11	6.4	Tsukuba City, Ibaraki Prefecture
E	03/29/11	04/04/11	36.3	Kashiwa City, Chiba Prefecture
F	03/30/11	03/30/11	ND	Shiroishi City, Miyagi Prefecture
G	04/03/11	04/03/11	ND (41.5)	Iwaki City, Fukushima Prefecture
H	04/12/11	04/13/11	ND (4.7)	Higashishirakawa-gun, Fukushima Prefecture
I	04/12/11	04/12/11	ND (6.8)	Fukushima City

These results were published by the Japan National Press Club of the Ministry of Health, Labour and Welfare (MHLW) on April 20. It was not until from April 24 to May 31 that, in response to this publication, the MHLW performed examinations of breast milk. Among 119 lactating women, I-131 was detected in breast milk samples collected from seven on April 24. The obtained results are shown in Table 7 (23). Regarding this evaluation, the MHLW says as follows: “… in this examination, no or very low levels of radioactive materials were detected in breast milk, despite the limited number of samples and regions,” “If needed, countermeasures, including evacuation orders and restrictions on consumption of food and drinking, were taken. Even if radioactive materials would transfer to breast milk through air, water and food, it is unlikely to have any impact on the health of infants," and "Given the various advantages of breast milk from a nutritional viewpoint, there is no need for concern and a person breastfeeding can continue living as usual free from excessive worry." Subsequently, the MHLW published the results of an additional examination of breast milk (108 people) performed from May 18 to June 3 (24), where no radioactive materials were detected in 101 people, a trace amount of radioactive cesium (2.0 to 6.7 Bq/Kg) was detected in 7 people and I-131 was not detected in any people.

Table 7 Results of Examinations in Breast Milk by the MHLW (Only People with Samples Radioactive Materials Detected) (23)

Name of Subject	Date of Breast Milk Sample Collection	I-131 (Bq/Kg)	Place of Residence
A	April 25	3.5	Iwaki City, Fukushima Prefecture
B	April 25	3.0	Hitachiomiya City, Ibaraki Prefecture
C	April 25	8.0	Mito City, Ibaraki Prefecture
D	April 25	2.2	Shimotsuma City, Ibaraki Prefecture
E	April 25	2.3	Kasama City, Ibaraki Prefecture
F	April 25	2.3	Kasama City, Ibaraki Prefecture
G	April 25	2.3	Chiba City

Table 8 Results of Examinations in Breast Milk by the Joso Consumer Cooperative (Only People with Samples Radioactive Materials Detected) (25)

Name of Subject	Date of Breast Milk Sample Collection	I-131 (Bq/L)	Place of Residence
1	March 22	48.8	Moriya City, Ibaraki Prefecture
2	March 24	11.3	Tsukuba City, Ibaraki Prefecture
3	March 30	55.9	Kashiwa City, Chiba Prefecture
4	March 31	12.0	Moriya City, Ibaraki Prefecture
5	March 31	9.8	Tsukuba City, Ibaraki Prefecture
6	April 6	16.1	Kashiwa City, Chiba Prefecture

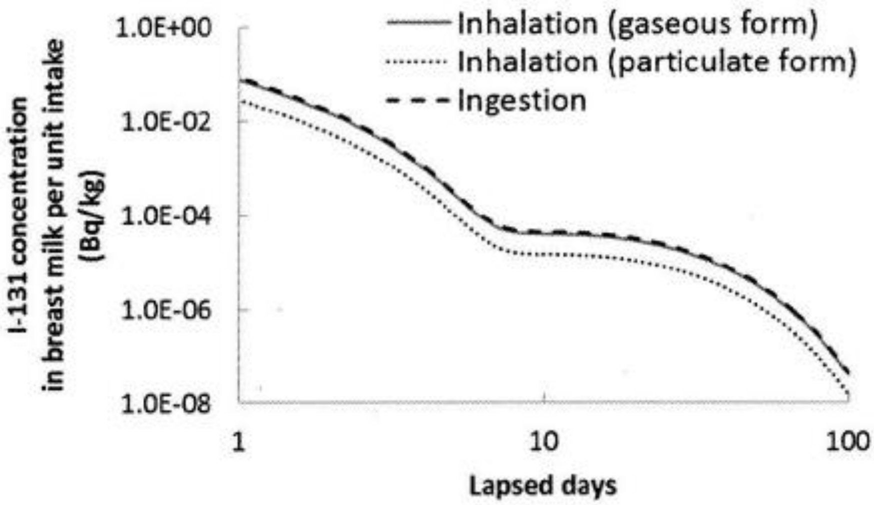
The other organization that performed an examination of I-131 in breast milk is the Joso Consumer Cooperative in Ibaraki Prefecture. This consumer cooperative detected I-131 in breast milk collected from six lactating women (25). Since then the Mother-and-Child Support Net has continued examinations, where a total of 421 samples have been analyzed. I-131 has not been detected since the detection in breast milk samples on May 5 (5.5 Bq/Kg: Iwaki City, Fukushima Prefecture). Radioactive cesium was detected in 24 people. Regarding the Fukushima nuclear accident, this is all the examination of breast milk that has been carried out. We compared the examination results by the MHLW with those by the Mother-and-Child Support Net, showing that the analyses by the Mother-and-Child Support Net have a high level of detection limit (2 to 10B Bq/Kg) due to the relationship between the amount of samples and measuring time, while the analyses by MHLW with a low level of detection limit (1 to 2 Bq/Kg) have higher detection rates. Accordingly, if the limit of detection was lowered in examinations performed by the Mother-and-child Support Net, radioactive materials were highly likely to be detected in much more breast milk.

(6-2) Findings from examination of breast milk

When a mother is breastfeeding her child and takes I-131 into her body through inhalation and food, what will happen? Regarding this question, ICRP or other organizations are proposing models related to the transition to each tissue in the body (internal pharmacokinetic model). For example, immediately after I-131 is taken into the body, approximately 50% is excreted in urine and 30% is absorbed into the thyroid gland. Considering the half-life of I-131 (8.04 days), 30% of the residual dose in the body is thought to be transferred to the breast milk. Kotaro Tani et al. from the National Institute of Radiological Sciences in Chiba City established a model to estimate the amounts of I-131 taken into the bodies of lactating women from the concentration in breast milk based on the above-mentioned internal pharmacokinetic model and published a paper (26). Tani et al. also published a paper in which exposure doses in a lactating woman were estimated by using this model from I-131 concentrations in breast milk measured by the MHLW (27).

Figure 9 is a graph cited from the paper, showing to what extent transition to the breast milk changes depending on the number of lapsed days after lactating women absorb 1 Bq of I-131 through inhalation and ingestion. Using this coefficient, the I-131 dose first inhaled or ingested by a lactating woman can be estimated from the I-131 concentration in breast milk on the examination day.

Figure9 Graph of Transfer Coefficient of I-131 (1 Bq) Taken into Maternal Body to Breast Milk (Reference 27)



In this paper, the authors insist that this model closely matched the transfer coefficient of I-131 to breast milk proposed by the ICRP-Pub 95.

Using this model, the absorbed I-131 doses in lactating women (March 15 single absorption model) and the exposure doses in the infants who took the breast milk were calculated based on the I-131 concentrations in breast milk examined by the MHLW (Table 8), and the results are shown in Table 9.

Mothers living in Mito City, Tsukubai City, Moriya City, and Hitachiomiya City in Ibaraki Prefecture, 100 to 200 km from the nuclear power plant, ingested several hundred thousand to one million becquerels of I-131 through inhalation, water, and vegetables. It is surprising that, consequently, not only did the thyroid equivalent dose in these mothers reach 100 to 400 mSv but also the thyroid equivalent dose in the infants who fed on the breast milk ranged from 300 to 1,200 mSv. However, these calculation results were not provided in any paper and did not become available to the public, except when reported at the Expert Conference of the Ministry of the Environment, held on May 20, 2014 (28). In the paper (27), Tani et al. did not use or discuss the estimated values for the doses of I-131 by lactating women through breast milk obtained by this pharmacokinetic model because in the author's opinion the values were too high to be realistic. Instead, they estimated the inhalation doses from I-131 concentration in the atmosphere at the time of the accident measured by Mito City and Tsukuba City and estimated the I-131 doses ingested by lactating women from the contamination levels of tap water and vegetables at the time. Based on both estimations, they assessed the I-131 exposure doses by lactating woman. The obtained results are cited in Table 10. The maximum thyroid equivalent dose is 3 mSv or lower in lactating women, as well as 11 mSv or lower in infants. The differences from Table 10 are just surprising. The authors are not saying that the pharmacokinetic model is wrong. However, which is correct?

Table 9 Doses of I-131 Taken by Lactating Woman and Thyroid Exposure Doses in Their Infants Obtained by Calculation from the Concentrations in Breast Milk (28)

Name of Subject	Measurement Value of Iodine-131 in Breast Milk (Bq/Kg)	Estimated Intake Dose in Lactating Women (Bq)	Effective Dose (mSv)	Equivalent Dose for the Thyroid Gland in Lactating Women (mSv) (mSv)	Equivalent Dose for the Thyroid Gland in Infants (Sv/Bq) (mSv)
A	3.5	439,000	10	189	524
B	3	376,000	8.3	162	449
C	8	1,000,000	22	432	1199
D	2.2	276,000	6.1	119	330
E	2.3	289,000	6.4	124	345
F	2.3	289,000	6.4	124	345
G	2.3	289,000	6.4	124	345

According to the ICRP-Pub95, CD3 concerning thyroid equivalent doses in infants caused by contamination of breast milk, when a mother breathes in 1 Bq of gaseous I-131 in the atmosphere, 28.3% of this is provided to the infant through breast milk, resulting in a thyroid equivalent dose of 1 μSv in the infant at 15 weeks of age. That is, when a mother inhales 1,000 Bq or 100,000 Bq, 1 mSv or 100 mSv, respectively, is passed on to the infant. These values are close to the estimated values by Tani et al. in Table 10. As already mentioned, the radioactive plume that moved inland on March 15, just after the accident, included high levels of I-131. Residents in Fukushima Prefecture were highly likely to have inhaled I-131 in amounts as high as several tens of thousands to one hundred thousand becquerels or higher on March 15, 2011, as stated in the paper by Hirayama et al (11). It cannot be ruled out that their thyroid equivalent doses ranged from several tens to several hundreds of mSv or higher. Professor Nobuya Unno et al. from Kitasato University also wrote a paper about an analysis of results from examinations of breast milk conducted by the MHLW and Mother-and-Child Support Net (29). In this paper, Unno et al., based on the idea from the example of Chernobyl that the I-131 contamination in breast milk was caused by water or food (milk in the case of Chernobyl) not by inhalation, estimated that the cause was contamination of vegetables and water for which contaminations were covered by the media at the time.

Table 10 Doses of I-131 Intake and Thyroid Equivalent Doses in Lactating Women and Infants (from Paper 27)

<table>
<tr><th rowspan="3">Place of Residence</th><th colspan="3">Lactating Woman</th><th colspan="3">Infant</th></tr>
<tr><th colspan="2">Inhalation</th><th rowspan="2">Ingestion</th><th colspan="2">Inhalation</th><th rowspan="2">Ingestion (breast milk)</th></tr>
<tr><th>I-131 in gaseous form</th><th>I-131 in particulate form</th><th>I-131 in gaseous form</th><th>I-131 in particulate form</th></tr>
<tr><td>Mito</td><td rowspan="2">2.8 mSv
(7.2 KBq)</td><td rowspan="2">0.84 mSv
(5.6 KBq)</td><td><0.38 mSv
<0.86 KBq</td><td rowspan="2">3.3 mSv
(1.0 KBq)</td><td rowspan="2">1.1 mSv
(0.78 KBq)</td><td rowspan="2">10-11 mSv
(2.8-3.1 KBq)</td></tr>
<tr><td>Kasama</td><td><0.36 mSv
<0.84 KBq</td></tr>
<tr><td>Tsukuba</td><td rowspan="2">0.23 mSv
(600 Bq)</td><td rowspan="2">0.14 mSv
(920 Bq)</td><td><0.22 mSv
<500 Bq</td><td rowspan="2">0.28 mSv
(80 Bq)</td><td rowspan="2">0.18 mSv
(130 Bq)</td><td>1.1-1.7 mSv
(290-450 Bq)</td></tr>
<tr><td>Moriya</td><td><0.26 mSv
<600 Bq</td><td>1.1-1.8 mSv
(290-480 Bq)</td></tr>
</table>

(6-3) Radiation exposure in the infants of woman soldiers who participated in Operation Tomodachi, launched by the US military

After the Fukushima nuclear accident, the United States Forces, Japan (USFJ), provided humanitarian assistance in the form of Operation Tomodachi, including delivering relief supplies to victims. Among a total of 53,000 soldiers who participated in this operation and their family members, 588 were pregnant women, 560 of whom gave birth after the operation. For 1,082 women who had infants less than 1 year of age, the United States Department of Defense assessed the exposure doses in the fetuses and infants exposed to the radiation during the two-month operation in order to publish a 110-page report (30). For this purpose, each USFJ base measured the concentrations of radioactive materials in the atmosphere since March 13, 2011. Although there is no evidence of direct analyses of breast milk, absorbed amounts of I-131 into the body were calculated from I-131 concentrations in the atmosphere and amounts inhaled by pregnant or lactating women (28 m3/day), and then exposure doses in fetuses and infants were calculated according to the ICRP acute absorption model. For infants, the exposure dose was obtained by adding I-131 ingested through breast milk to that inhaled directly into the body through inhalation. One example of the results is shown in Table 11.

The iodine-131 concentrations in the atmosphere used for this calculation, for example in Yokota base from March 14 to 15, were up to 19 Bq/m3. Other than that, there is a report about exposure doses of 53,000 people, including soldiers who participated in Operation Tomodachi (31). In any case, given that the exposure of the thyroid gland of infants of the U.S. Army women who worked at Yokota base 240 km away from the Fukushima nuclear power plant, which caused the accident, ranged as much as 8.9 to 21 mSv, it cannot be overestimated how much radiation exposure there was of the thyroid gland in infants in Fukushima and Ibaraki prefectures, where the concentrations in the atmosphere were much greater.

Table 11 Exposure Doses in Infants Who Were Exposed Due to the U.S. Operation Tomodachi (Total of I-131 exposure doses through breast milk and breathing) (30)

Name of the US Army Base	Effective Exposure Dose (mSv)	Thyroid Equivalent Dose (mSv)
Misawa base	0.03-0.07	0.04-0.16
Yokota base	0.58-1.3	8.9-21
Akasaka Press Center	0.54-1.2	8.9-21
Atsugi base	0.48-1.1	7.7-18
Yokosuka base	0.45-1.0	7.7-18
Camp Fuji	0.15-0.37	2.5-6.1
Iwakuni base	0.02-0.05	0.36-0.89
Sasebo base	0.03-0.07	0.46-1.1

Note: Among these, there are no data on women conducting operations at J-village located near the nuclear power plant

(6-4) Opinions concerning assessment methods of I-131 radiation exposure dose

As mentioned above, radiation exposure in the thyroid gland by I-131 cannot be accurately assessed because various errors, including Bkg, tend to occur. In particular, in the measurement method where a dosimeter is directly applied to the thyroid gland, the measurements are easily affected by contamination of the environment. Also, accurate assessment becomes impossible as time passes due to the half-life of I-131 (8 days). On the contrary, it is a bioassay using breast milk and urine that allows for biologically accurate measurements. With this method, measurements are not easily affected by Bkg, and prolonged measurement times can lower the limit of detection, resulting in higher detection rates. In the case of using breast milk as samples, however, this method has the disadvantage that the number of samples is limited because collection of a large volume of samples is often difficult due to differences between each individual lactating woman.

On the other hand, the bioassay using urine, which has been rarely performed to date, has many advantages as follows: (1) A large volume of sample can be collected because anyone without regard to the age and gender excretes urine every day (1 to 3 liters) and (2) continuous measurements for an individual are possible. (3) Based on previous studies, 50% of I-131 taken into the body is excreted in urine and 30% is accumulated in the thyroid gland, which results in high concentrations leading to reliable detection accuracy. Considering these conditions, the most reliable method to assess I-131 exposure doses may be a urine examination conducted immediately after the accident.

(7) Reactions of the Government and academic societies

As mentioned above, the MHLW issued a notification on April 30, 2011 saying, "Considering the trace amounts of radioactivity detected and the restriction on the consumption of air, water, and foods (standards for I-131 at the time were 300 Bq/Kg for milk and drinking water and 2,000 Bq/Kg for vegetables and other foods), even if radioactivity were to be transferred to breast milk, there should be no significant impact; therefore, a mother may provide her baby with breast milk free from anxiety." Was this issued for the purpose of soothing mothers who were worried about radioactivity detected in breast milk, I wonder (32)? On May 2, a similar opinion was published from the Japan Society of Obstetrics and Gynecology (33). However, the MHLW conducted the examination of breast milk more than one month after the nuclear accident when I-131 became difficult to detect due to its short half-life (8.04 days) and after many mothers already provided their infants with contaminated breast milk. It is clearly risky that the government issues reports based on ambiguous grounds and that specialists write papers even though scientifically sound assessment is impossible.

In contrast to the responses of the Japanese government and the Japan Society of Obstetrics and Gynecology, the American College of Obstetricians and Gynecologists placed a policy proposal titled Radioactive Accidents and Children in the academic journal (35) *Pediatrics* (2003), saying “In a case where radioactivity is released into the atmosphere due to a nuclear test, nuclear accident, accident during transportation, or terrorism, children may be significantly affected. Particularly, given that iodine-131 is likely to significantly affect the thyroid gland of infants, policymakers should encourage mothers to stop providing breast milk.” In response to this proposal, researchers from the National Cancer Institute and Memorial Sloan Kettering Cancer Center in New York commented, “In the case of a radioactive accident when the distribution of stable iodine is difficult, breastfeeding should be stopped to prevent exposure of infants.” (36)

The Japan Science Council, which is the center of learning, published a report on September 1, 2017, titled *Effects of Radiation Exposure on Children and Issues in the Future——To Utilize the Available Scientific Findings in Fukushima* (34). In this Japan Science Council report, the equivalent doses of thyroid gland exposure are estimated to be 16 to 35 mSv for adults, 27 to 58 mSv for children 10 years of age and 47 to 83 mSv for children 1 year of age. However, the contents are almost an exact copy of the Annex A of United Nations Scientific Committee on the Effects of Atomic Radiation (UNSCEAR) 2013 Report. There is no verification conducted by the council itself about any scientific rationale. The UNSCEAR 2013 Report was in turn based on the following two papers: the above-mentioned paper written by Shoji et al. from Hirosaki University (14) and the paper written by Eunjoo Kim et al. from the National Institute of Radiological Sciences based on the results from thyroid examinations in 1,080 people, which we mentioned above in the report from the Nuclear Safety Commission (19). Other than that, no direct investigations and analytical data on exposure of the thyroid gland are available. Nevertheless, the media and many critics, including scientists, currently give the UNSCEAR report absolute priority and are insisting that “exposure to radiation in the thyroid gland in Fukushima was low.”

（8）Conclusion

Seven years have elapsed since the Fukushima nuclear accident. The government and Fukushima Prefecture are trying to greatly reduce the scale of the various examinations regarding radioactivity, which they have conducted to date. As one of these reductions, the scale of the thyroid examinations in children whose age was under 18 years at the time of the accident in Fukushima Prefecture has been reduced. They are insisting that the reason for this reduction is that detection of thyroid carcinoma because of overdiagnosis may cause children and parents unnecessary worry and anxiety, leading to reputational damage. Also, they plan to conduct examinations not in all children, which have been covered to date, but only in children who want to, because increases in thyroid carcinoma are considered not attributable to radiation exposure based on markedly low levels of exposure doses in Fukushima unlike Chernobyl. This is a completely irrational and unscientific opinion. Whereas they admit the increases in thyroid carcinoma, if they will not investigate the cause at all and only reduce the scale of the examinations, the cause will not be understandable. In the case of Chernobyl, the increases in childhood thyroid carcinoma actually peaked ten years after the accident. The number is still increasing in Fukushima. The argument that the exposure doses are low is unreliable because only investigations, which are based on a detection method using very little data and causing probable errors and underestimation as mentioned above, have been conducted.

One of the major causes of this is that no immediate investigations and analyses were conducted after the accident. Particularly, I-131, which is the cause of thyroid carcinoma, has a half-life of 8 days, leading to difficulty in detection and a large error when more than one month has elapsed after the accident. The reason is that the government and electric power companies who have continued promoting nuclear power plants in Japan, as well as scientists in the Nuclear Power Village, all assumed that a severe accident involving a nuclear power plant would never occur in Japan and, therefore, did not prepare for the worst-case scenario. In the case of Chernobyl, a large-scale investigation could be conducted at the time of the emergency. The reason is said to be that ironically, at the time of the accident in 1986, the government of the Soviet Union had a system to measure radioactivity in the case of nuclear war caused by the Cold War between the Soviet Union and the United States in.

A reduction in the scale of the examinations is not only for thyroid carcinoma. Currently, approximately 3,000 monitoring posts located at various places in the prefecture are measuring and displaying air dose rates. Among them, the Nuclear Regulatory Agency of the Japanese government currently plans to remove 2,400 monitoring posts located where the air dose rate has declined to not more than 0.23 μSv/h. As for the reason, the Nuclear Regulatory Agency says that "… the existence of monitoring posts causes reputational damage, as if the place has a high level of exposure." Just the opposite is true. Residents in Fukushima have experienced various specific damages and losses caused by radioactivity to date; therefore, they know well that a low measured value of radioactivity is the very thing that gives a sense of security. If the monitoring posts are removed, in the case of any accident in the ongoing decommissioning of the nuclear power plant, they would not be able to know facthe level and so become anxious instead, and reputational damage would be reignited in people outside the area who do not know the facts. Furthermore, Fukushima Prefecture plans to reduce the scale of inspections of every bag of rice produced in Fukushima, which have been conducted to date. Certainly, seven years have elapsed since the accident and concentrations of radioactive cesium in rice produced in Fukushima have significantly reduced. Among 9,800,000 bags investigated in the 2017 fiscal year, radioactivity above the LOD (25 Bq/Kg) was detected in only 35 bags (0.0004%). However, the reputational damage for rice produced in Fukushima is continuing, and rice farmers' trouble is not yet over. One of the causes is the current standard value in food (100 Bq/Kg). No matter how many times you tell urban consumers that the value is under the standard, they are still not convinced. Because they think about the possible value of a 90 Bq/Kg. If the scale of the inspection of every bag is reduced, the possibility cannot be ruled out that the reputational damage could be further widespread.

Recently, there is an argument that talking about the increase in thyroid carcinoma and contamination problem in Fukushima would lead to discrimination against residents in Fukushima. It is true that some persons exposed to radiation in Hiroshima and Nagasaki lived all their lives while hiding the fact that they had been exposed to radiation even from their spouses or children for fear of being discriminated against. However, it is also true that, as a result, this masked the fact and consequences of radiation exposure, resulting in an uncertain locus of responsibility and thereby leading to being unable to receive compensation. Regarding discrimination due to the fact that a person has been exposed to radiation, the person who discriminates is the problem while the person exposed to radiation bears no responsibility. Trivializing radiation exposure is a huge problem originating from Hiroshima and Nagasaki. Too much fear of being discriminated against resulted in masking the fact of radiation exposure, thereby leading to trivializing the damage caused by radioactivity. Ironically, Professor Shunichi Yamashita from Nagasaki University, acclaimed as an expert in radioactivity and who was installed as a vice-president of Fukushima Medical University after the Fukushima nuclear accident, and Professor Kenji Kamiya from the Research Institute for Radiation Biology and Medicine, Hiroshima University, both insisted everywhere that radioactivity in Fukushima is not frightening.”

This is nothing but reflecting this history. Efforts should be made to understand again that the fact of radiation exposure is different from the problem of discrimination and to make people consider the idea that discrimination is not allowed as common sense whatever the facts are. It is clear that these various problems all relate to the measurement of radioactivity, which is a basic system. Although, unfortunately, the nuclear accident happened, aiming to keep its impact to a minimum through immediate and accurate measurements and analyses is essential. Conducting a widespread publicity campaign that sounds as if the fact of radiation exposure does not exist based on uncertain information can never guarantee the safety and security of the victims of the nuclear accident.

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