Thyroid equivalent doses due to radioiodine(I-131) intake for evacuees caused by the nuclear accident in Fukushima

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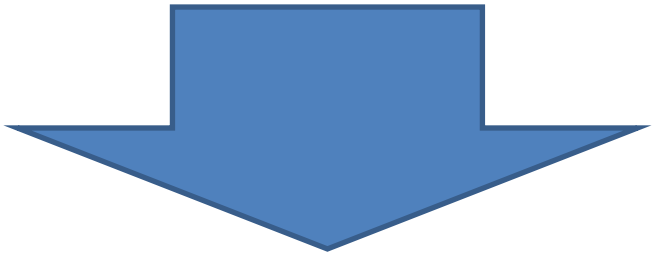
INTRODUCTION

- After nuclear accident in Fukushima on March 11th 2011, every effort has been made so as to evaluate radiological and environmental effects until now.
- Exposure features under the initial situation have not yet been clarified because there were not enough data for the evaluation for restructuring of initial exposures.
- No systematic data on exposures of general public to short-lived radionuclides, in particular, radioiodine(I-131) were available.
- Only several small groups including Hirosaki University carried out radioactivity measurements in the thyroid.
  - Ref. Tokonami et al., *Scientific Reports*, 2012
  - 45 Evacuees from coastal area and 17 residents in Tsushima District, Namie Town were examined for ^{131}I radioactivity in the thyroid.

INTRODUCTION

- **However, the number of measurements was too small to refer to the thyroid dose for many evacuees from the nuclear accident.**
- **Several months later, WBC inspection was initiated for evaluation of their internal doses though radioiodine activity was not completely detected.**



An innovative approach is required to solve this problem.

INTRODUCTION

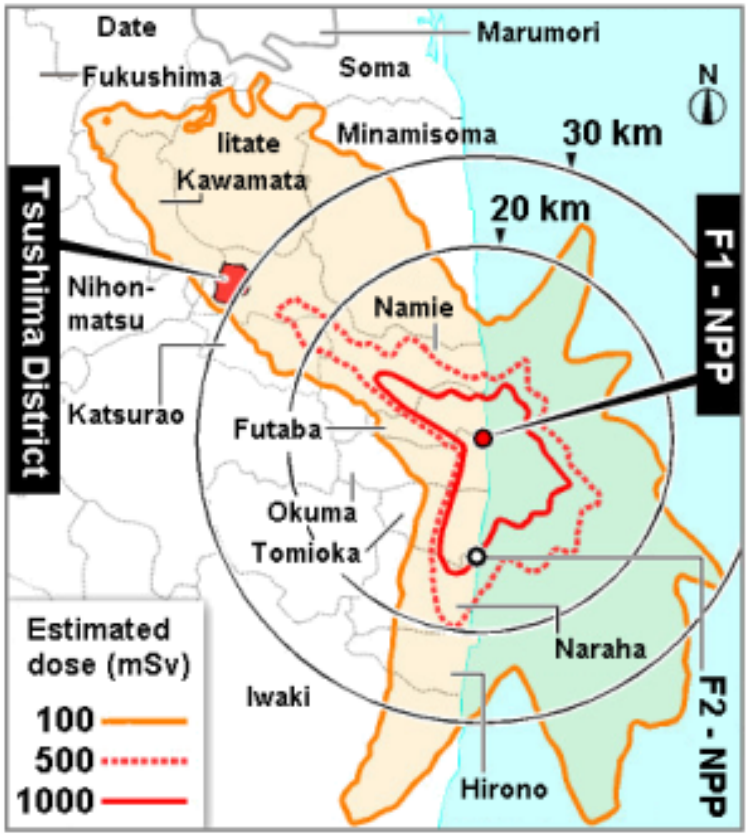


Figure Thyroid dose contour map. The dose for one–year-old infants in the areas surrounding the reactor was estimated by SPEEDI (System for Prediction of Environmental Emergency Dose Information). Tsushima District of Namie Town is located within the 30-km-radius zone around the reactor. The figure was provided by the Asahi Shinbun and modified.

- More than 6000 people evacuated from coastal areas in Namie Town and stayed at Tsushima District from March 12th to 15th 2011.
- A radioactive plume reached Tsushima District in the afternoon of March 15th 2011.

MATERIALS AND METHODS

I-131 activity measurements in the thyroid

Measurement period	April 12th - 16th, 2011
Number of measurement	45 evacuees from coastal area 17 residents at Namie Town Total: **62 persons** (the measurement after informed consent)
Range of age	0 - 83 years old (accurate information on age was not available for **eight** people)
Measuring instrument	3" × 3" NaI(Tl) scintillation spectrometer
Measurement time	300 sec (B.G : 300 sec)

*After the detection head was wrapped with a plastic foil so as to avoid radioactive contamination, it was placed on their neck and started the measurement.

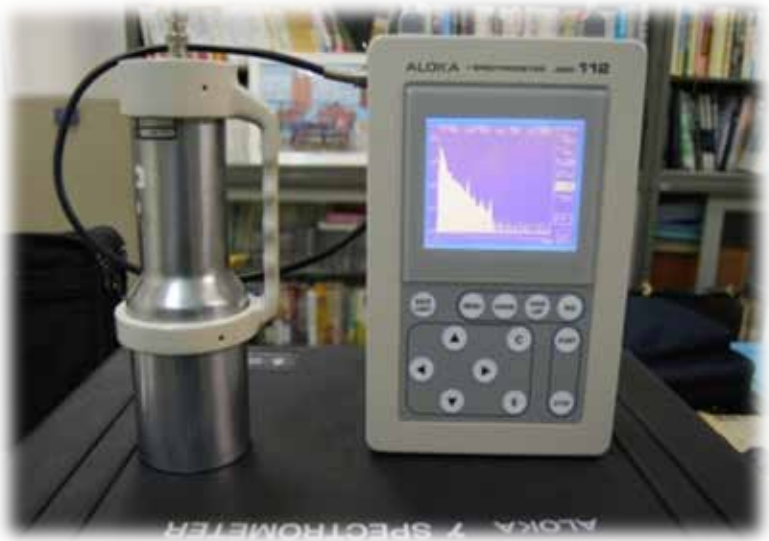


Fig.3 Photo of 3" × 3" NaI(Tl) scintillation spectrometer. (JSM-112, Hitachi Aloka Medical, Ltd., Tokyo)

Fig.4 I-131 activity in the thyroid measurements for evacuees.

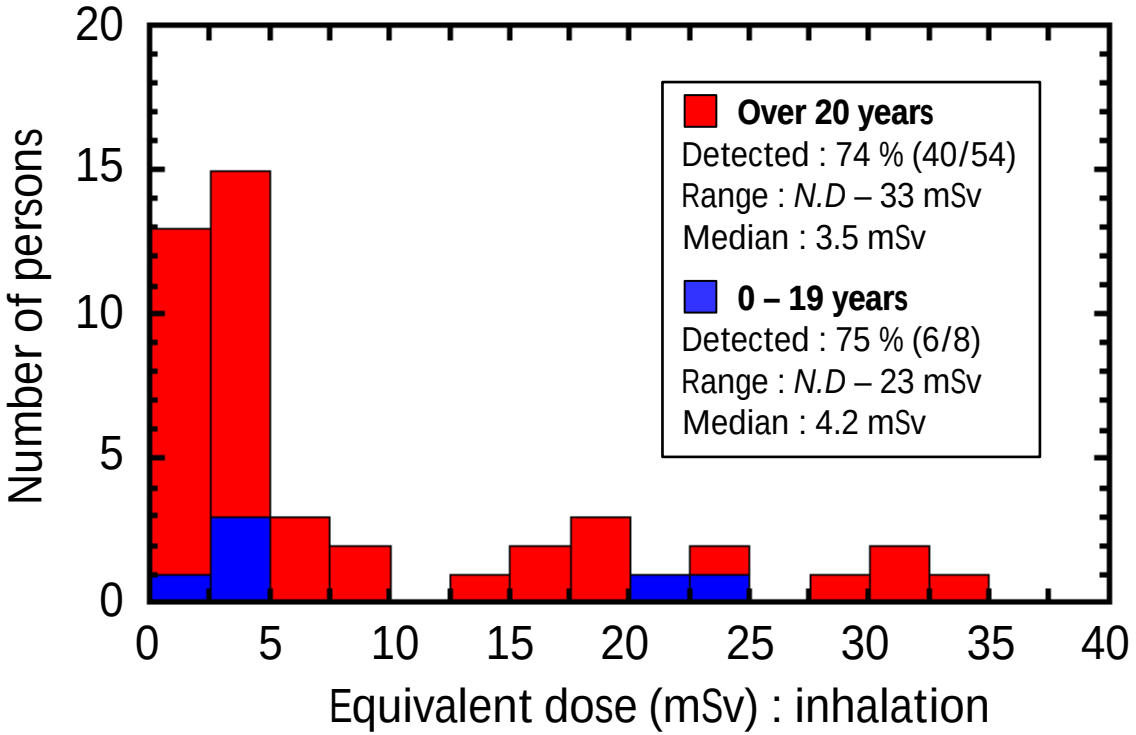
I-131 ACTIVITY IN THE THYROID AND EQUIVALENT DOSE

Number of persons in age groups, range of thyroid activity measured on April 12th to 16th, 2011, and thyroid equivalent dose

Age group	Number of persons	I-131 thyroid activity range (kBq)	Thyroid dose range (mSv) : inhalation
0 - 9	5	*N.D* - 0.017	*N.D* - **21**
10 - 19	3	0.090 - 0.54	3.8 - 23
20 - 29	9	*N.D* - 0.59	*N.D* - 16
30 - 39	6	*N.D* - 0.17	*N.D*- 4.4
40 - 49	4	*N.D* - 1.5	*N.D* - 33
50 - 59	10	*N.D* - 1.1	*N.D* - 31
60 - 69	12	*N.D* - 0.20	*N.D*- 5.3
70 - 79	3	0.090 - 1.5	2.3 - 31
80-	2	*N.D* - 0.70	*N.D* - 19
Unknown	8	*N.D* - 1.4	*N.D* - 28

- I-131 activity in the thyroid by inhalation for all the subjects ranged from ***N.D*** **to 1.5 kBq**.
- Thyroid equivalent doses by inhalation for all the subjects ranged from ***N.D*** **to 33 mSv**.

I-131 ACTIVITY IN THYROID AND EQUIVALENT DOSE



Distribution of measured persons by thyroid equivalent dose from inhalation of I-131.
This dose was calculated according to I-131 activity in thyroid and the age-dependent equivalent thyroid dose coefficient.

The thyroid equivalent dose assessed in this study were **much smaller** than the mean thyroid dose in the Chernobyl accident (490 mSv in evacuees).

THYROID EQUIVALENT DOSE FOR YOUNG CHILDREN

p For the estimation of the **retrospective thyroid dose** by inhalation for young children.

↓

Maximum atmospheric I-131 concentration estimated from the thyroid activity of evacuees

p **Calculation of the atmospheric I-131 concentration**

$$C_I = \frac{A_T}{(0.5)^{t/T_{eff}}} \times (V \times i)^{-1}$$

C_I : Atmospheric I-131 concentration (Bq m^{-3})

t : Elapsed time between March 15th and the measured date

T_{eff} : Effective half-life of I-131

V : Breathing volume over 4 hours (m^3)*

i : Thyroid uptake factor (i = 0.3)

*The typical value at each age given by ICRP Publication 71.
*4 hours: from 13:00 to 17:00 on March 15th

p **Estimation of the retrospective thyroid dose for young children**

$$D = C_{I\text{-}max} \times V \times f$$

D : Retrospective thyroid dose (mSv)

$C_{I\text{-}max}$: Maximum atmospheric I-131 concentration (Bq m^{-3})

V : Breathing volume over 4 hours (m^3)

f : Equivalent thyroid dose coefficient

THYROID EQUIVALENT DOSE FOR YOUNG CHILDREN

Table Estimation of possible thyroid equivalent dose for children using the assumed maximum atmospheric I-131 concentration (23 kBq m^{-3})

Age	Breathing volume per 4 hour (m^3)*	Total I-131 intake activity (kBq)	Thyroid dose coefficient (mSv kBq^{-1})*	Thyroid equivalent dose (mSv)
3 months	0.48	10.9 ± 0.9	3.3	36 ± 3
1 year	0.86	19.7 ± 1.6	3.2	63 ± 5
5 years	1.45	33.4 ± 2.6	1.9	63 ± 5
10 years	2.55	58.5 ± 4.6	1.0	56 ± 4
15 years	3.35	76.9 ± 6.1	0.6	48 ± 4

* Ref : ICRP Publication **71**, *Age-dependent Doses to Members of the Public from Intake of Radionuclides -Part 4 Inhalation Dose Coefficients.*

- Thyroid equivalent dose for children could **exceed 50 mSv**.

However…

- We did not consider I-132 exposure due to lack of information in this work.

THYROID EQUIVALENT DOSE FOR YOUNG CHILDREN

Table Estimation of possible thyroid equivalent dose for children using the assumed maximum atmospheric I-131 concentration (23 kBq m^{-3})

Age	Breathing volume per 4 hour (m^3)*	Total I-131 intake activity (kBq)	Thyroid dose coefficient (mSv kBq^{-1})*	Thyroid equivalent dose (mSv)
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1 year	0.86	19.7 ± 1.6	3.2	63 ± 5
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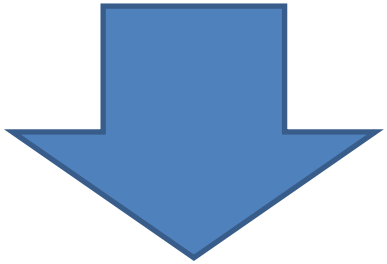
* Ref : ICRP Publication **71**, *Age-dependent Doses to Members of the Public from Intake of Radionuclides -Part 4 Inhalation Dose Coefficients.*

- If children remained in Tsushima District after the radioactive plume arrived in the afternoon of March 15th
  - à They might have experienced **further exposure to I-131**

- Since the maximum I-131 concentration was obtained from an adult's activity
  - à Inhaled activity by infants could be **less** because they **usually stay indoors** in cold winter weather

MOTIVATION OF THE SECOND STUDY

Not only radioiodine but also radiocesium (Cs-134 and -137) in the body were detected in the survey carried out by us in April 2011.



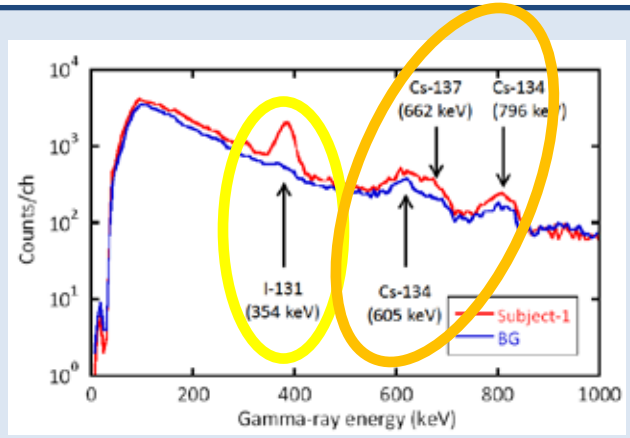
Assumption: The ratio between iodine and cesium was constant when inhaled if these radionuclides in the same plume were inhaled at the same place.

Uncertainties:

1. **When did they inhale?**
2. **How did they take an action?**
3. **Additional intake of radiocesium through another pathway?**
4. **Personal difference on biological parameters such as biological half-life and transfer rate to the thyroid.**

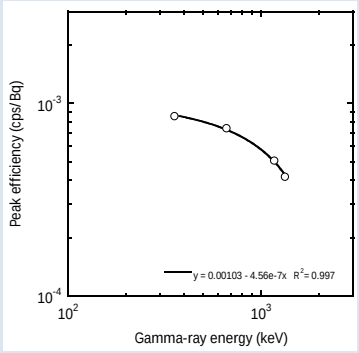
OVERVIEW OF THE SECOND STUDY

Thyroid dose survey for general public



Gamma spectrum obtained by our work

Determination of counting efficiency for calculation of radiocesium activity in the body



Ratio between I-131 and Cs-134 (or Cs-137)

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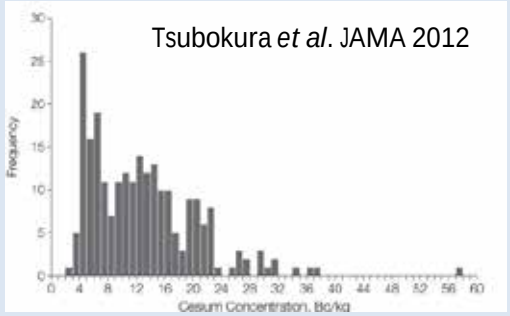
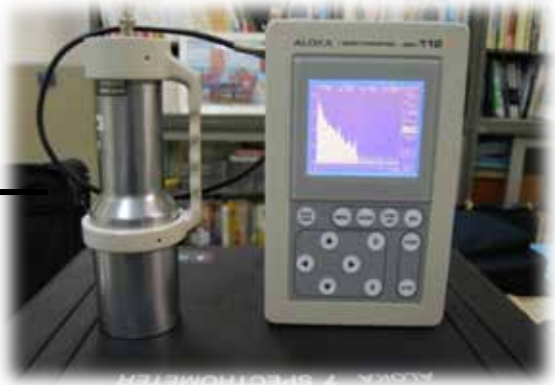
Possible to calculate the thyroid dose using radioiodine activity estimated by WBC data?

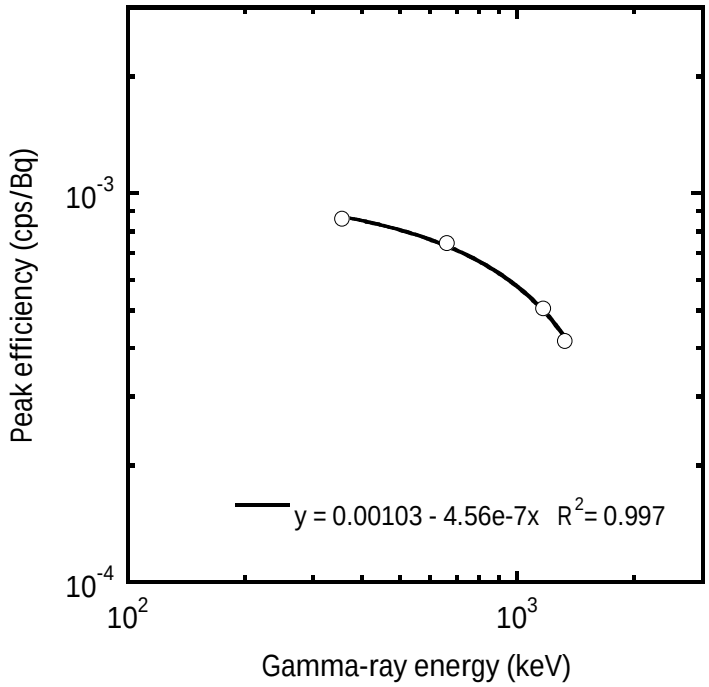


CALIBRATION OF MEASURING EQUIPMENT (UNDER THE SAME GEOMETRIC ARRANGEMENT)

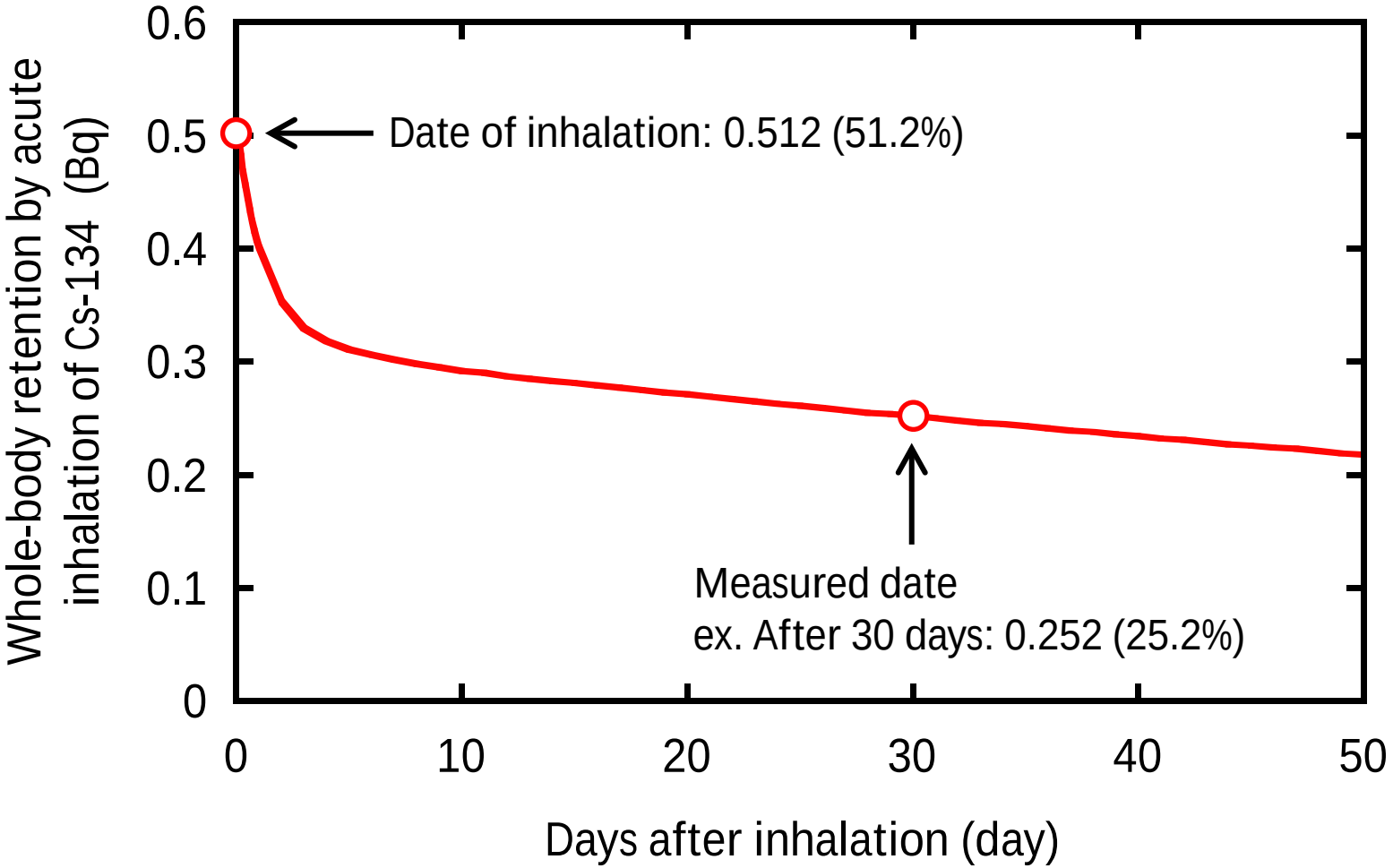
Calibration experiment for gamma spectrometer (JSM-112) using BOMAB phantom. This experiment was carried out at NIRS.



3 inches NaI(Tl) scintillation spectrometer
(JSM-112, Hitachi Aloka Medical, Ltd., Tokyo)



CALCULATION OF THE WHOLE-BODY RETENTION DUE TO ACUTE INHALATION OF ^{134}CS ON MARCH 15TH, 2011



- **Data of whole-body retention due to acute inhalation of ^{134}Cs used the database "MONDAL" developed by NIRS.**

RATIO BETWEEN I-131 AND CS-134 (=^{131}I/^{134}CS)

Definition:

$$Ratio = \frac{I - 131\ activity\ on\ the\ date\ of\ intake}{Cs - 134\ activity\ on\ the\ date\ of\ intake}$$

The ratio was obtained from 5 persons statistically available among 62 persons inspected as follows:

- Geometric mean= 0.23
- Maximum= 0.87

$$^{131}I = 0.87 \times {}^{134}Cs$$

THYROID DOSE EVALUATION FOR PEOPLE IN NAMIE TOWN

Age	No. of persons (male)	%	No. of persons (female)	%	No. of total	%
0-9	30	14.2%	29	15.5%	59	14.8%
10-19	118	55.7%	75	40.1%	193	48.4%
20-29	9	4.2%	28	15.0%	37	9.3%
30-39	43	20.3%	46	24.6%	89	22.3%
40-49	10	4.7%	6	3.2%	16	4.0%
50-59	1	0.5%	2	1.1%	3	0.8%
60-69	1	0.5%	1	0.5%	2	0.5%
70-79	0	0.0%	0	0.0%	0	0.0%
80-89	0	0.0%	0	0.0%	0	0.0%
90-99	0	0.0%	0	0.0%	0	0.0%
合計	212	100%	187	100%	399	100%

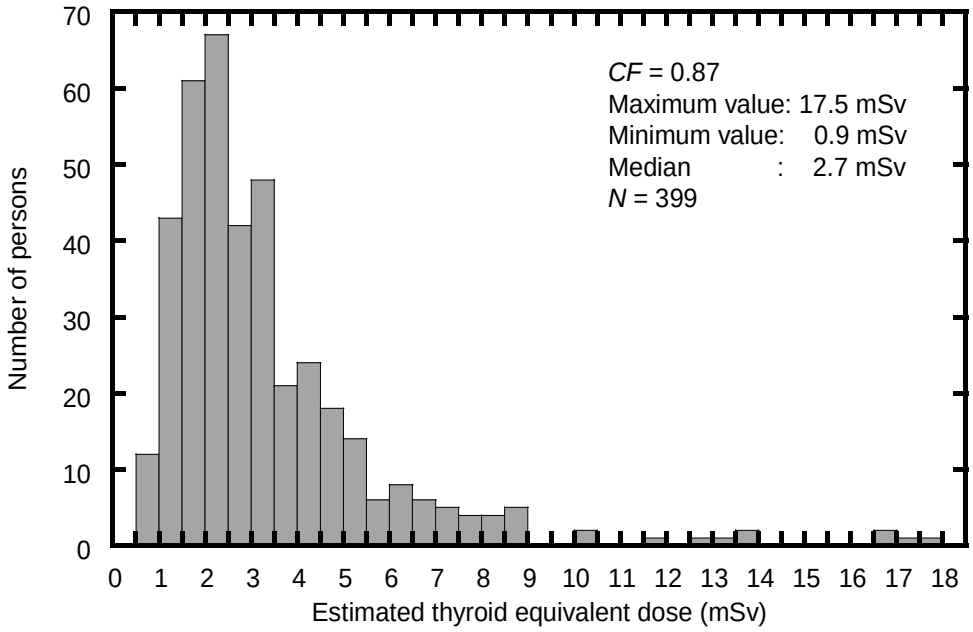
Thyroid dose estimated using WBC data obtained from July to August 2011.
399 persons whose radiocesium activities were statistically detected among 2393 persons.
Additional intake due to ingestion was not considered.

THYROID DOSES FOR PEOPLE IN NAMIE TOWN (MAXIMUM APPLIED)

Thyroid dose frequent distribution using CF=0.87

Thyroid dose (mSv)	Number of persons	%
D < 1	12	3.0
1 ≦ D < 2	103	25.8
2 ≦ D < 3	109	27.3
3 ≦ D < 4	70	17.5
4 ≦ D < 5	42	10.5
5 ≦ D < 6	20	5.0
6 ≦ D < 7	14	3.5
7 ≦ D < 8	9	2.3
8 ≦ D < 9	9	2.3
9 ≦ D < 10	0	0.0
10 ≦ D < 11	2	0.5
11 ≦ D < 12	1	0.3
12 ≦ D < 13	1	0.3
13 ≦ D < 14	3	0.8
14 ≦ D < 15	0	0.0
D ≧ 15	4	1.0
SUM	399	100

Min: 0.9 mSv
Max: 18 mSv (17 y)
Under 20 y: 252人
Adults : 147人



CONCLUSION

- when CF=0.87 (conservative estimate);
  - All the subjects in Namie Town: below 20 mSv
  - +95% of persons: below 10 mSv
- The trend is similar to our first study.
  - Median= 3.5/4.2 mSv (first)
  - Median=2.7 mSv (second)

FUTURE WORK

- As technical issues to be solved and be analyzed;
  - Inconsistency of $^{131}I/^{134}Cs$ with other approaches such as source term analyses
    - Thyroid uptake factor properly assigned?
  - Correlation with radioactivity in environmental samples taken during the initial phase (March and April 2011)
  - Application of this technique to other regions
    - Estimation of radioactivity in the body/thyroid using radioactivity in environmental samples