Annex VI of Technical Volume 4
INFORMATION ON MEASUREMENT STUDIES INVESTIGATED IN THE PRODUCTION OF TECHNICAL VOLUME 4

VI–1. WHOLE BODY COUNTER MEASUREMENTS

VI–1.1. Study 1: Pilot study of more highly exposed evacuees

Internal dose assessment surveys were undertaken by Fukushima Prefecture, in cooperation with the National Institute of Radiological Sciences (NIRS) and the Japan Atomic Energy Agency (JAEA). NIRS carried out an internal exposure survey on Fukushima Prefectural residents [VI–1]. Initial measurements were taken between 27 June and 16 July 2011. The survey focused on residents who lived in areas associated with high doses and measured the amount of radionuclides within the whole body, including the thyroid and in urine samples. A total of 122 participants — 90 residents from Namie Town, 20 residents from Iitate Village, and 12 residents from Kawamata Town — were initially enrolled in the survey, and 109 subjects were surveyed in follow-up examinations. Whole-body counters (WBCs) were used to detect activity from ^{134}Cs and ^{137}Cs. Urine bioassays were used to determine a cut-off value for the WBC measurements. Minimum detectable activities (MDA) of ^{137}Cs and ^{134}Cs in three minute measurements in a bed geometry were 570 Bq and 320 Bq, respectively.

From the results of the WBC, ^{134}Cs was detected in 52 out of 109 people (47.7%), with the highest value being 3100 Bq. ^{137}Cs was detected in 32 out of 109 people (29.4%), with the highest value being 3800 Bq. These values may be compared with the approximately 4000 Bq of the naturally occurring radionuclide ^{40}K which is constantly present in the adult body and contributes an annual effective dose of about 0.37 mSv. Both ^{134}Cs and ^{137}Cs were detected in 26 out of 109 people (23.9%). ^{131}I was not detected in any subject some three months after the main releases. The internal dose from ^{134}Cs and ^{137}Cs combined was less than 1 mSv for these individuals [VI–2].

The ^{131}I in the thyroid was measured by a thyroid monitor with an HPGe detector (MDA is 38 Bq for a 3 minute measurement), but none was detected in this survey. Urine bioassays were performed using the spot urine, mainly first catch urine, but the relationship between the results of this method and WBC was not confirmed in this survey.

VI–1.2. Study 2: JAEA extended study of evacuees

JAEA began internal exposure surveying of evacuees on 11 July 2011. The report of Momose et al. [VI–2] details the series of WBC measurements undertaken on about 10 000 evacuees from July 2011 to January 2012. The presence of ^{134}Cs and ^{137}Cs could be detected in the body in only 20% of the study subjects (with a minimum detectable activity of about 300 Bq for ^{137}Cs and 300 Bq for ^{134}Cs in two minutes of measurement in a standing geometry Canberra FASTSCAN counter, and of 370 Bq and 340 Bq, respectively, in three minutes of measurement in a chair geometry). The 50th percentile values of effective dose from the intake of ^{134}Cs and ^{137}Cs since March 2011 were estimated to be about 0.025 mSv to adults and about 0.02 mSv to adolescents, assuming an acute initial intake via inhalation on 12 March 2011. In almost all the study subjects, the effective dose was estimated to be below 1 mSv, and the 95th percentile value of internal doses to all subjects was of the order of 0.1 mSv. Deposition on clothes may have affected the measurement results up to the end of December 2011. To avoid false positive detection caused by contamination on clothing, subjects were asked to change into contamination free gowns before the beginning of measurement in January 2012. In a number of cases, this was a significant source of error, and the actual doses were therefore likely to have been smaller than the estimated values. In some cases, re-measurement after changing clothing reduced reported body activities to below detection levels.

VI–1.3. Study 3: Health examination for citizens in Fukushima Prefecture

These doses are based on the assumption that intake was by inhalation in March 2011, and are therefore cautious, particularly concerning the measurements made in late 2012 and 2013. If it had been assumed that there were chronic low levels of ingestion of the caesium isotopes throughout the period, the estimated doses would be lower.

VI–1.4. Study 4: Hirata Central Hospital measurements

A group at the University of Tokyo reported on the results of WBC measurements carried out at Hirata Central Hospital in Fukushima Prefecture between October 2011 and November 2012 [VI–3]. This study found that levels of ^{137}Cs were well below the detectable threshold of 300 Bq per body (about 4 Bq/kg for a 70 kg adult or 10 Bq/kg for a 30 kg child) for 9886 (88%) of the residents tested between October 2011 and February 2012. For the remaining 12% (1340 people), the ^{137}Cs concentration generally ranged between 10 and 50 Bq/kg. However, 21 785 (99%) of the residents tested between March and November 2012 had no detectable concentration, while the remaining 1% (212 people) mainly had body burdens between around 10 and 25 Bq/kg. This confirmed that most of the radionuclide intake occurred soon after the accident. A policy introduced in March 2012 for subjects to change from their usual clothes into hospital gowns for measurement contributed to this sharp decrease. Based on the WBC measurements of adults conducted between October 2011 and February 2012, the average effective dose from the intake of ^{134}Cs and ^{137}Cs since March 2011 was assessed to be about 0.02 to 0.07 mSv.

The highest concentrations — estimated to correspond to effective doses of about 1 mSv/y — were found in four people, aged between 66 and 74, who were discovered to have been regularly eating unscreened food, such as wild mushrooms, wild boar and freshwater fish. However, after following advice not to eat such food, their internal radionuclides content significantly dropped.

VI–1.5. Study 5: Minamisoma City screening programme

A voluntary screening programme for levels of caesium (^{134}Cs and ^{137}Cs) was conducted between 26 September 2011 and 31 March 2012, for residents of Minamisoma City, located 23 km north of the Fukushima Daiichi NPP [VI–4]. Many residents had been evacuated, but by August 2011, approximately half of them had returned. Persons monitored using a WBC were aged 6 years or older. Detection limits were 210 Bq for ^{134}Cs and 250 Bq for ^{137}Cs with a 2-minute scan. Caesium content was measured as both total body activity and concentration by body weight (Bq/kg) and was reported as median values with ranges (minimum to maximum). Committed effective doses were estimated based on the assumption of acute caesium inhalation immediately after the accident in adults, and on that of chronic caesium ingestion in children. Reasons for the difference in intake assumptions are not explained in the paper (Ref. [VI-5]), but it may have been thought that the shorter biological half-life of radiocaesium in children justified a chronic ingestion scenario, since measurements were not carried out until 6 months after the accident. Reported differences between adults and children may at least in part be attributable to the different exposure pathway assumptions. This illustrates the difficulties in using WBC measurements to estimate radiation doses.

A total of 9498 residents enrolled in the study, which was 24% of the registered population on 15 August 2011. The sample consisted of 1432 children (720 girls with a median [range] age of 11 [6–15] years) and 8066 adults (4512 women with a median [range] age, 44 [15–97] years).

A total of 3286 individuals (34.6%) had detectable levels of caesium. Caesium was detected in 235 children (16.4%), ranging from 210 to 2953 Bq (median, 590 Bq), with a concentration of 2.8 to 57.9 Bq/kg (median, 11.9 Bq/kg). In contrast, 3051 adults (37.8%) had detectable levels of caesium, ranging from 210 to 12 771 Bq (median, 744 Bq), with a concentration of 2.3 to 196.5 Bq/kg (median,

11.4 Bq/kg). This difference in proportion of persons with detectable activities was statistically significant between adults and children. The authors considered this difference to reflect differences in caesium metabolism or greater attention to food and water consumption or changes in outdoor activity in children. Estimated committed effective doses were less than 1 mSv in all but one resident (1.07 mSv) based on the assumptions on intake given above.

VI–1.6. Study 6: Measurements in Nagasaki

In Nagasaki, approximately 1200 km away from Fukushima, the internal radioactivity in evacuees and short term visitors to Fukushima was measured by a WBC beginning on 15 March 2011 [VI–5]. A horizontal bed-type scanning WBC equipped with two NaI (Tl) scintillation detectors was used for measurements on 173 people who had stayed in Fukushima Prefecture between 11 March and 10 April 2011. The average length of stay was 4.8 days. The internal radioactivity was converted to an estimated amount of intake according to an acute inhalation scenario, and then the committed effective dose and the thyroid equivalent dose were evaluated. ^{131}I, ^{134}Cs and ^{137}Cs were detected in more than 30% of examined individuals. In subjects who stayed in Fukushima from 12 March to 18 March, the detection rate was approximately 50% higher for each radionuclide and 44% higher for all three nuclides. The highest estimated committed effective dose and thyroid equivalent dose were 1 mSv and 20 mSv, respectively, from internal radionuclides.

VI–1.7. Study 15: Thyroid measurements in Iwaki City, Kawamata Town and Iitate Village

Over the period of 26 to 30 March 2011, a total of 1080 measurements were taken in Iwaki City, Kawamata Town and Iitate Village on children aged 1 to 15 years using hand held dose rate instruments (Kim et al. [VI–6] and Hosokawa et al. [VI–7]).

Thyroid equivalent doses less than 30 mSv were estimated for almost all of the subjects, irrespective of the different chronic and acute intake scenarios assumed. It may be noted that in Kim et al. (2012) [VI–6] the predicted thyroid activity for a 'screening level' of 0.2 μSv/h external throat measurements of 15-year-olds was given as 6030 Bq, and this was calculated to give rise to a dose to the thyroid of a 12–17-year-old of 16 mSv for an intake scenario of chronic intake for 12 days and measurement on the 13th day. However, if the intake had all been on the first day rather than spread over 12 days, the estimated absorbed dose to the thyroid would have been higher by more than a factor of 2. This demonstrates some of the difficulties in interpreting direct measurements on people where it is not clear when the intake occurred and whether it was by inhalation or ingestion.

VI–1.8. Study 16: Thyroid measurements from residents and evacuees in Namie Town

There was a study [VI–8] conducted measurements of ^{131}I activity in the thyroid of 62 residents and evacuees from the Tsushima district of Namie Town and the coastal area of Minamisoma City during the period of 12–16 April 2011. A 3 × 3 inch NaI (Tl) scintillation spectrometer was placed at the neck of examinees. Net thyroid and background count rates were determined from the detected gamma spectra. Thyroid equivalent dose coefficients for iodine in elemental form were used, as given in ICRP Publication 71 [VI–9], with a thyroid uptake factor equal to 0.3. The authors detected ^{131}I in 46 people in the group, in 39 of the 45 people evacuated from coastal areas, and in 7 of the 17 residents from the Tsushima District; they estimated that equivalent thyroid doses of the children aged less than 10 years were in the range from none detected to 20 mSv. The median thyroid equivalent doses for children (under 20 years of age) and adults were 4.2 and 3.5 mSv, respectively.

Some of these children were known to have stayed in areas such as Iitate Village, which had relatively high levels of radionuclides in the environment, from 11 to 18 March. As the most conservative scenario, the authors estimated the thyroid dose to children, using the atmospheric ^{131}I concentration

assessed from the highest thyroid measurement in adults (1.5 kBq). From this, a possible maximum thyroid equivalent thyroid dose from ^{131}I intake for an infant of about 60 mSv was derived.

VI–1.9. Study 17: Whole body and thyroid measurements conducted for visitors

Morita et al. [VI–10] evaluated the thyroid dose from ^{131}I and the committed effective dose from both ^{134}Cs and ^{137}Cs for 196 residents and short term visitors to Fukushima Prefecture in the period of 11 March to 20 April 2011. The horizontal bed-type WBC consists of two NaI (Tl) scintillation detectors (with 8 inches in diameter and 4 inches in thickness and placed in a shielding room covered with 20 cm thick steel and 3 mm thick lead layers). The thyroid dose and effective dose were estimated using the measurement results obtained from the WBC. The minimum detectable activity (MDA) for ^{131}I, ^{134}Cs and ^{137}Cs was 30 Bq, 33 Bq and 33 Bq, respectively. ^{131}I, ^{134}Cs and ^{137}Cs were detected in 49 out of 196 persons who were in Fukushima Prefecture during the given period. Study 18: Measurements carried out by experts from the Russian Federation.

Another study involved a team of experts from the Russian Federation that made three trips to Japan in 2011–2012. During the first trip (8–20 April 2011), the team measured the exposure rate outdoors and indoors, the level of contamination of the territory of the embassy of the Russian Federation in Tokyo and the embassy cars, and provided radiation monitoring of the embassy staff, members of their families, other Russian citizens (in total 268 people) with respect to determination of the content of ^{131}I in the thyroid and ^{134}Cs and ^{137}Cs in the body [VI–11]. A mobile scintillation spectrometer (InSpector 1000 Canberra) was used for radiation monitoring. Calibration of this spectrometer for the purpose of assessing the ^{131}I thyroidal content and radiocaesium in the body had been carried out in Moscow before being shipped to Japan. A protocol of measuring, interviewing and recording of the results of radiation monitoring was developed. Special attention was given to avoiding surface radioactive contamination of the body and clothes of people during the measuring procedure. People were interviewed with respect to their residence history, dietary habits and use of KI pills.

In April 2011, only 3 of 268 people exceeded the minimum detectable activity (MDA), which was equal to 100 Bq of ^{131}I in the thyroid during two minutes of measurement and reached up to 130 Bq of ^{131}I [VI–11]. It should be noted that none of the 784 people monitored during the three trips in 2011-2012 exceeded the MDA (1800 Bq ^{137}Cs and ^{134}Cs for a five minutes count). Assuming a cautious scenario, which was single inhalation intake on 15 March 2011, when radioactive fallout was observed in Tokyo area, the maximum thyroid equivalent dose was assessed as 2 mSv for an adult, and 4 mSv for a 1-year-old child. As previously discussed, experience following the Chernobyl accident showed that the distribution of radioiodine and radiocaesium content in the residents of a settlement is satisfactorily described by a log-normal function with a typical ratio between maximum and average values of a factor of about 10. Taking this into account, it is reasonable to assume that the average thyroid equivalent dose is estimated to be equal to 0.2 mSv for an adult and 0.4 mSv for 1-year-old child.

VI–1.10. Study 19: Iitate Village and Kawamata Town

In the study by Kamada, et al. of residents at Iitate Village and Kawamata Town, ^{131}I was detected in the urine of 5 of the 15 residents analysed 54 and 78–85 days after 11 March 2011. Estimated equivalent doses to the thyroid were between 27 and 66 mSv.

VI–1.11. Other studies

A study of the results of WBC measurements of nearly 1500 school children in the town of Miharu, Fukushima Prefecture, found that, although 54 had detectable levels of ^{137}Cs in the winter of 2011, by the autumn of 2012 no children were found to have detectable levels [VI–3]. The researchers noted: “These results are not conclusive for the prefecture as a whole, but are consistent with results obtained

from other municipalities in the prefecture, and with prefectural data. This does not mean, however, that Fukushima residents are free of internal exposure risks, as evidenced by a small number of senior citizens whose body burden exceeded 100 Bq/kg" [VI–3].

External and internal radiation doses were estimated for 15 residents who lived approximately 37 km north-west of the Fukushima Daiichi NPP at Iitate Village and Kawamata Town. Residents were interviewed on where they stayed and what they ate after the accident. To estimate external dose, the ambient dose rate around each person's home was measured, and cumulative effective doses up to 54 days after the deposition were calculated. To estimate committed effective dose, urinary bioassays were performed using a low background germanium spectrometer on 54 days and 78–85 days after the deposition. The average cumulative effective (external) dose was estimated to be 8.4 mSv for adults and 5.1 mSv for children. The average committed effective (internal) dose from ^{134}Cs and ^{137}Cs was 0.055 mSv for adults and 0.029 mSv for children [VI–12].

Another study [VI–13] to estimate absorbed doses to the thyroid was also evaluated. The thyroid dose was estimated for residents in Namie Town for whom the WBC measurement data exists and was derived from intake ratio of ^{131}I to ^{134}Cs. The intake ratio was estimated using previously measured gamma spectra by the authors [VI–8]. The maximum internal dose to the thyroid to ^{131}I was estimated to be 18 mSv. However, the limited data on which it was based, together with other major uncertainties associated with the study, mean that the results are not presented here.

The thyroid equivalent doses to children in the Tokyo region from ingestion based on radioactive iodine concentrations in food and drinks have also been estimated [VI–14]. The effects of countermeasures (restrictions on the distribution of foods and the distribution of bottled water for infants) on reducing intake were also evaluated. The average thyroid equivalent doses without countermeasures from 21 March 2011 were 0.42 mSv in adults, 1.49 mSv in children, and 2.08 mSv in infants. Those with countermeasures were 0.28, 0.97, and 1.14 mSv, respectively, which constitute reductions of 33%, 35%, and 45%. Drinking water contributed more to intake by adults and children than foods. The intake of ^{131}I within the first two weeks was more than 80% of the estimated intake, owing to its short half-life, indicating that rapid countermeasures are important in reducing intake.

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