Whole-Body Counter(WBC) and food radiocesium contamination surveys in Namie, Fukushima Prefecture

Yoichiro Hosokawa¹*, Kazuki Nomura¹, Eiki Tsushima², Kohsei Kudo¹, Yuka Noto³, Yoshiko Nishizawa³

¹ Department of Radiation Science, Graduate School of Health Sciences, Hirosaki University, Hirosaki, Aomori, Japan, ² Department of Comprehensive Rehabilitation Science, Graduate School of Health Sciences, Hirosaki University, Hirosaki, Aomori, Japan, ³ Department of Nursing Science, Graduate School of Health Sciences, Hirosaki University, Hirosaki, Aomori, Japan

* hosokawa@hirosaki-u.ac.jp

Abstract

Purpose

This study examined the internal Cs exposure of residents and the Cs present in food products produced in Namie. Whole-body counter (WBC) was used for the measurement of internal exposure per each whole body of examinees.

Methods

The food products which appeared to be used for consumption, were brought by residents and commercially available food items were excluded. Most of them were wild plants or food items produced by residents. Four years of data from April 2012 to March 2013 (fiscal 2012) and April 2015 to March 2016 (Fiscal 2015) were analyzed and studied.

Results

The average radioactivity measured by WBC was approximately 5 Bq for Cs-134, and 20 Bq for Cs-137 and the average committed effective dose was approximately 1 μSv. The average for the residents with detectable radioactivity was 25 μSv, and the human health effects are considered to be extremely low risk. However, the radioactivity of the affected individuals showed a higher value than the theoretical attenuation rate. The majority (83.2%) of individuals exhibiting radioactivity were over 50 years old. The number of food products brought in for detection decreased as the study period progressed, but the number of food products with radioactivity had increased. While the items with a higher detection rate of radioactivity included fruits such as citron and persimmon, shiitake mushrooms exhibited the highest radioactivity. Moreover, the radioactivity of seven items in these 10 items decreased from fiscal 2012 to fiscal 2015. Mushrooms had high radioactivity and were produced over a wide area.
Conclusion

We suggest that the elderly try to enjoy life and eat wild plants in moderation while inspecting food products. Therefore, we will continue to work in raising awareness of radiation and its potential presence in food products and thus the continuing necessity of monitoring radioactivity in food in the future.

Introduction

Large amounts of artificial radionuclides such as radioiodine and radiocesium were released by the Fukushima Daiichi Nuclear Power Plant (FDNPP) accident in March 2011 [1]. Namie is located in the northern part of Fukushima Prefecture in Japan, and its population was around 21,000 when the Great East Japan earthquake struck. Namie is located about 4 km away from the power plant and the residents were evacuated considering the impact of the accident [2], (Fig 1). The exposure of the thyroid to I-131 was considered problematic at the initial stages of the accident based on the lessons learned from the Chernobyl nuclear power plant [3,4]. There have been extensive discussions on the exposure dose of the thyroid and the possibility of increased thyroid cancer rates due to the Fukushima nuclear power plant disaster. Therefore, even now thyroid screening tests are being conducted on the children of Fukushima [5,6].

A few months after the accident, the level of I-131 decreased due to its short life, and Cs-134 and Cs-137 became the main radionuclides detected in the environment around FDNPP [7]. Fortunately, Cs-134 and Cs-137 are strong $\gamma$-emitters, which allows for their fast, straightforward, and reliable detection and quantification using $\gamma$-spectroscopy. Sr-90 was also released by FDNPP, however, the maximum concentration was assumed to be 0.3% of Cs-137 concentration after April 2012 according to the report of Japan government [8]. According to the safety standards of radioactivity in foods, the acceptable level of radioactivity has been determined as 100Bq/kg by the Japanese government. Thus, the radioactivity of Cs-134 and Cs-137 is mainly estimated by a whole body counter (WBC) and a food radiation detector in order to monitor internal radiation exposure in the human body and food in Fukushima.

Several studies have assessed internal radiation exposure to radiocesium using WBC [7]. However, there are few that have discussed the internal exposure of Cs and the contamination of everyday food products [9]. This study examined the internal Cs exposure of Namie residents and the Cs present in food products produced in Namie. The number of food products brought for detection decreased as the study period progressed, but the number of food products with radioactivity had increased. While the items with a higher detection rate of radioactivity included fruits such as citron and persimmon, shiitake mushrooms exhibited the highest radioactivity. Moreover, the radioactivity of seven items in these 10 items decreased from fiscal 2012 to fiscal 2015.

Materials and methods

Whole-body counter (WBC) tests were conducted on the residents of Namie town at the makeshift Tsushima clinic in the town of Nihonmatsu. All examinees wanted to be tested for internal exposure. Measurements were performed for 2 minutes after the initial identification of Cs using FASTSCAN (FASTSCAN®, Canberra Inc., USA). Minimum detectable amount (MDA) values of Cs-134 and Cs-137 were defined 300 Bq and 300 Bq in a 2 min measurement for the stand-up WBC, and 340 Bq and 370 Bq in a 3 min measurement for chair type WBC [10]. WBC was calibrated with the adult male-sized bottle mannequin absorption (BOMAB)
phantom (American National Standards Institute, 1999) as a standard source in the USA and Canada once every three years. It was calibrated with the Canberra RMC-II (MODEL 2257) Transfer phantom (Canberra Inc., USA) and the Standard Radionuclide source (Eckert & Ziegler, Berliner, Germany), which includes Cd-109, Co-57, Ce-139, Hg-203, Sn-113, Cs-137, Y-88, Co-60 once a year. Traceability of these methods is assured by the National Institute of Standards and Technology. The difference in WBC counting efficiencies between the calibration used by the BOMAB phantom and the transfer phantom is under 10% as confirmed by Momose et al. [10].

The WBC measurement value of this study is the radioactivity per each whole body. Measurements on children under 3 years old were conducted with the children standing on a 90 cm high chair. For children over 3 years old and less than 130 cm tall, measurements conducted with them standing on a 30 cm high pedestal. Residents registering radioactivity that exceeded the detection limits were asked to participate in a survey. Committed effective doses were calculated to consider an age-appropriate dose conversion factor and residual radioactivity in human bodies [11]. Residents were informed that results of the study would be used for research before the measurements and survey.

The radioactivity of the food products was measured at the Namie town office because the residents of the town had been evacuated. The food products which were used for consumption...
were considered, and commercially available food items were excluded. Most of them were wild plants or food items produced by residents. Three types of instruments were used for measurement (Table 1): (CAN-OSP-NAI 8Hitachi Co., Ltd. Tokyo, Japan) was used for measurements when the resident consented to the food being crushed, and FD-08Cs1000-1-50 (Techno Co., Ltd. Osaka, Japan) was used when such consent was not obtained. When foods were measured, they were cut finely with a knife, and placed into a Marinelli plastic beaker without any gaps between food pieces. For food that could not be cut, the samples were put in an appropriate plastic box and the box was put at the center of the measuring area. Samples weighing more than 500 g were considered. SEG-EMS was used for accurate measurements when the sample weight was less than 500 g, or when the radioactivity could not be measured with simple methods.

Four years data from April 2012 to March 2013 (fiscal 2012) and April 2015 to March 2016 (Fiscal 2015) were analyzed and studied. All data were analyzed using the software SPSS 16.0J for Windows. This study was approved by the Committee of Medical Ethics of Hirosaki University Graduate School of Medicine, Hirosaki, Japan.

Results

The number of persons tested for WBC, radioactivity, and committed effective dose from fiscal 2012 to fiscal 2015 are shown in Table 2. The overall number of persons tested, and the number of individuals detected with radioactivity both decreased with age. The average

Table 1. Types of machines used to survey food.

| machine | measurement time | character | detector | detection limit | BG-measuring method and | calibration source |
|---------|-----------------|-----------|----------|----------------|-------------------------|-------------------|
| CAN-OSP-NAI (Hitachi Co. Ltd. Tokyo, Japan) | 30m | simplified non-destructive measurement | NaI | 25Bq/kg | blank: 90min water: 120min | Cs-137 JRA |
| FD-08Cs 1000-1-50 (Techno Co. Ltd. Osaka, Japan) | 20m | simplified destructive measurement | NaI | 25Bq/kg | water: 40000sec | Cs-134+Cs-137 JRA |
| SEG-EMS (Seiko Co. Ltd. Tokyo, Japan) | 4000s | precision measurement | Ge semiconductor | 1Bq/kg | blank: 50000sec | Co-60 JRA |

blank: The radioactivity was measured when machine was empty.
water: The radioactivity of purified water was measured by placing a plastic beaker with purified water in the machine and measuring the count.
JRA: Japan Radioisotope Association.

https://doi.org/10.1371/journal.pone.0174549.t001

Table 2. Number of the study participants and results of whole body counter.

|                  | total            | fiscal 2012 | fiscal 2013 | fiscal 2014 | fiscal 2015 |
|------------------|------------------|-------------|-------------|-------------|-------------|
| total number (Male) | 16279(7625)     | 7645(3590)  | 4570(2117)  | 2816(1317)  | 1248(601)   |
| number of individual persons(Male) | 11622(5399)     | 7334(3402)  | 4438(2053)  | 2774(1298)  | 1223(581)   |
| average age(Male) | 50.9(50.2)       | 50.8(49.9)  | 51.4(50.9)  | 53.3(53.2)  | 56.1(55.6)  |
| committed effective dose(SD)μSv | 1.0(9.3)        | 1.3(10.5)   | 0.4(4.2)    | 0.6(5.4)    | 1.0(8.9)    |
| radioactivity mean of 134Cs(SD)Bq | 5.3(60.2)       | 8.5(80.6)   | 2.2(30.6)   | 2.3(31.9)   | 3.4(46.1)   |
| radioactivity mean of 137Cs(SD)Bq | 17.1(148.2)     | 22.8(174.3) | 7.5(80.4)   | 14.4(119.8) | 23.1(208.8) |
| number of individual persons detected radioactivity (Male) | 495(342)        | 374(258)    | 61(41)      | 60(47)      | 32(21)      |
| committed effective dose(SD)μSv | 24.7(39.2)      | 24.6(39.0)  | 24.9(28.3)  | 25.8(25.0)  | 33.3(41.4)  |
| radioactivity mean of 134Cs(SD)Bq | 342.0(351.9)    | 337.0(385.8)| 328.1(178.3) | 353.9(192.3) | 471.1(288.3) |
| radioactivity mean of 137Cs(SD)Bq | 521.1(638.1)    | 470.4(645.2)| 545.9(422.2)| 622.8(496.6)| 825.4(958.6)|
| maximum of committed effective dose μSv | 502             | 502         | 125         | 146         | 192         |
| number of 50 years old and over persons (Male) | 412(281)        | 300(202)    | 54(37)      | 60(47)      | 29(19)      |

https://doi.org/10.1371/journal.pone.0174549.t002
Radioactivity was approximately 5 Bq for Cs-134, and 20 Bq for Cs-137 and the average committed effective dose was approximately 1 μSv. The majority (83.2%) of individuals exhibiting radioactivity were over 50 years old with men accounting for 68.2%. The average committed effective dose was 24.65 μSv for individuals detected with radioactivity. The mean value of radioactivity for individuals exhibiting radioactivity is shown in Fig 2. The trend of increasing Cs-137 radioactivity was observed for individuals detected with radioactivity, and a statistically significant difference was observed for the mean values in 2012 and 2015 with the one-way analysis of variance (p < 0.05). Cs-134 and Cs-137 attenuation rates of individuals detected two or more times was compared with the theoretical attenuation rate based on the effective half-life (100 days) to examine the cause [9]. The results are shown in Fig 3. The radioactivity of the affected individuals showed a higher value than the theoretical attenuation rate.

Namie residents provided 4,542 food products for testing from 2012 to 2015 and radioactivity was detected in 2081 (45.8%). The number of food products exhibiting radioactivity was compared between fiscal 2012 and fiscal 2015 (Fig 4). The number of food products brought for detection decreased as the study period progressed, but the number of food products with radioactivity had increased. The radioactivity of Cs-134 and Cs-137 detected in the food products are shown in Table 3. Over the years, food products detected with only Cs-134 decreased, and food products exhibiting only Cs-137 increased. Also, a decreasing trend of the radioactivity ratio of Cs-134 to Cs-137 was observed, and it was assumed that Cs-134 had attenuated. The food items exhibiting high detection radioactivity rates are shown in Table 4. While the items with a higher detection rate of radioactivity included such as citron and persimmon, and shiitake mushrooms exhibited the highest radioactivity. Moreover, the radioactivity of seven items in these 10 items decreased from fiscal 2012 to fiscal 2015. Mushrooms had high radioactivity.
radioactivity and were produced over a wide area. Fig 5 shows the number of the mushrooms detected with radioactivity on the geography. Mushroom activity was higher in areas with a high external gamma dose rate. The results of the fiscal 2013 questionnaire are shown in Table 5 because the recovery was the highest in 4 years. The persons who answered "did not care" regarding contaminated food products with radioactivity were the most in all persons who had radioactivity detected.

**Discussion**

Residents of Namie continue to live in shelters; approximately 70% were evacuated within Fukushima and the rest outside of Fukushima. Temporary housing was set up at 30 locations in Fukushima, and as of November 2016, there were about 2,900 residents living in this temporary housing. However, the dose rate (less than 20mSv/y) has decreased with the progress in decontamination of the Namie town region, and the restrictions based on "Evacuation Directive Lift Prepared Area" and "Restricted Habitation Area" are scheduled to be lifted in March 2017. Short-term accommodations not recognized earlier were specially acknowledged as special accommodations in September 2016. We analyzed the Cs WBC measurement results of
residents who were evacuated to the Nihonmatsu area as well as the radioactivity of food brought with them, which was not distributed as products.

The average radioactivity of Namie residents measured via WBC, was approximately 5 Bq for Cs-134 and 20 Bq for Cs-137. WBC results for the residents of Korosten City, Ukraine were reported as 37.2 kBq/kg [12] 10 years after the 1996 Chernobyl nuclear power plant disaster. On comparing the results obtained from the Namie residents with the residents of Korosten City, it was observed that radioactivity was much lower than that of Korosten City considering our values are systemic whole body values. Bernhardsson et al. reported on the internal and external exposure of inhabitants living in the Bryansk region of Russia between 1990–2008 [13]. They observed that, in 2008, the average effective dose [sum of external and internal exposure dose] of Cs-137 to which Chernobyl residents were exposed was estimated as 0.3 mSv/y, which corresponds to 8% and 1% of the estimated annual dose in 1990 and 1986, respectively. Hoshi reported that the mean value of annual internal dose averaged for the whole set of measurements is 0.21 mSv, and the median of the individual dose distribution is 0.12 mSv/y from 1991–1996 for children residing in the western part of Bryansk Oblast [14]. When compared to these values, the committed effective dose for Namie residents is very low; the average for all examined individuals was 1 μSv (Cs was undetectable in 95.65% of the population). The committed effective dose was also very low with an average of 24.65 μSv for individuals with detectable radioactivity.

### Table 3. Results of radiocesium in food.

|                          | total | fiscal 2012 | fiscal 2013 | fiscal 2014 | fiscal 2015 |
|--------------------------|-------|-------------|-------------|-------------|-------------|
| number of food items detected only Cs-134 | 35    | 29          | 3           | 3           | 0           |
| number of food items detected only Cs-137 | 348   | 74          | 46          | 110         | 118         |
| mean of Cs-134 radioactivity/mean of Cs-137 radioactivity | 0.49  | 0.7         | 0.49        | 0.36        | 0.42        |

https://doi.org/10.1371/journal.pone.0174549.t003
However, both a tendency for internal exposure to increase with each passing year and a
trend of radioactivity not to attenuate in the follow-up for the individuals exhibiting radioac-
tivity was observed. Moreover, the questionnaire revealed that the individuals displaying
radioactivity were mostly men over the age of 50 and were not concerned about contaminated
food products. From these results, we can infer that individuals displaying radioactivity con-
tinued to eat foods contaminated with radioactivity. In a study that investigated smokers, risk
perception was found to be higher in women as compared to men, and women had a higher
tendency to avoid risks. [15,16]. The fact that individuals detected with radioactivity are
mainly men over 50 years of age, and that they continued to eat foods with detectable radioac-
tivity is consistent with this reasoning.

Radioactivity limits in foods were set under the Food Sanitation Act and have been in force
since April 1, 2012 in Japan. Limits were set in accordance with the concept that the annual maxi-
num permissible dose of radioactive cesium in foods should not exceed 1 mSv. Furthermore, the
“limit of 100 Bq/kg” for general foods was determined by choosing the most rigorous limits
among the calculated values [17]. We got the impression that the limits were understood by the
residents when we spoke to them. The increase in food products with detectable radioactivity over
time, despite the decrease in the number of food products brought in for inspection was due to an
increasing awareness among residents of possibly radioactive plants within their collection region.

The overall radioactivity of food products decreased in our study because the half-life of Cs-
134 is 2 years. However, there were also many food items that exceeded the limits. Mushrooms,

| Table 4. Food of high detection rate. |
|---------------------------------------|
| title                      | subtitle | citron | persimmon | petasites | plum | bamboo shoot | bracken | shiitake mushroom | kiwi fruit | aralia Sprout | chestnut |
|-----------------------------|----------|--------|-----------|-----------|------|--------------|---------|------------------|------------|--------------|---------|
| rank                        |          | 1      | 2         | 3         | 4    | 5            | 6       | 7                | 8          | 9            | 10      |
| total number                |          | 199    | 223       | 189       | 151  | 137          | 120     | 104              | 85         | 82           | 58      |
| detected number by radioactivity |        | 196 (98%)a | 193(87%) | 138(73%) | 127 (84%) | 127(93%) | 85(71%) | 80(77%)          | 78 (92%)   | 77(94%)      | 54(93%) |
| fiscal 2012 radioactivity means±SD (Bq/kg) |        | 1320 ±1255 | 313±596 | 61±70 | 225 ±323 | 451±758 | 75±49 | 12276±21440     | 333 ±318 | 309±301      | 1162 ±2822 |
| maximum (Bq/kg)             |          | 3160   | 2265      | 322      | 1098 | 2880         | 193     | 121000           | 1150       | 1125         | 10210   |
| minimum (Bq/kg)             |          | 12     | 15        | 11       | 10   | 15           | 13      | 19               | 32         | 29           | 31      |
| median (Bq/kg)              |          | 564    | 66        | 39       | 71   | 119          | 58      | 4070             | 241        | 148          | 147     |
| fiscal 2013 radioactivity means±SD (Bq/kg) |        | 460 ±400 | 158±112 | 204±345 | 162 ±140 | 494±819 | 454 ±801 | 4999±8289       | 147 ±108   | 264±348      | 203±228 |
| maximum (Bq/kg)             |          | 1658   | 514       | 1099     | 621  | 2666         | 2550    | 29920            | 341        | 1270         | 780     |
| minimum (Bq/kg)             |          | 78     | 27        | 13       | 31   | 8            | 8       | 8                | 26         | 31           | 22      |
| median (Bq/kg)              |          | 335    | 103       | 38       | 92   | 186          | 28      | 973              | 92         | 67           | 102     |
| fiscal 2014 radioactivity means±SD (Bq/kg) |        | 332 ±635 | 65±122 | 754 ±2392 | 93 ±102 | 319±355 | 467 ±905 | 4608±5646 | 62±72 | 471±679 | 267±432 |
| maximum (Bq/kg)             |          | 3943   | 740       | 14709    | 493  | 1460         | 3810    | 164600           | 270        | 2767         | 1130    |
| minimum (Bq/kg)             |          | 23     | 5         | 9        | 6    | 10           | 22      | 253              | 7          | 21           | 5       |
| median (Bq/kg)              |          | 176    | 36        | 144      | 68   | 220          | 118     | 2269             | 31         | 128          | 67      |
| fiscal 2015 radioactivity means±SD (Bq/kg) |        | 270 ±445 | 51±50 | 192±297 | 52±42 | 368±538 | 182 ±224 | 4317±6275 | 53±42 | 711±930 | 157±198 |
| maximum (Bq/kg)             |          | 2742   | 274       | 1489     | 161  | 2364         | 1065    | 21436            | 146        | 4178         | 779     |
| minimum (Bq/kg)             |          | 16     | 4         | 5        | 6    | 7            | 8       | 11               | 4          | 14           | 19      |
| median (Bq/kg)              |          | 121    | 33        | 69       | 35   | 168          | 94      | 742              | 38         | 385          | 73      |

a detected number/total number.

https://doi.org/10.1371/journal.pone.0174549.t004
in particular, were found to be radioactive. Based on the 1986 Chernobyl Nuclear Power Plant, it is well known that radiocesium tends to concentrate in wild mushrooms [18]. Nakashima found that radioactive cesium exceeding 100 Bq/kg was detected in 125 of 154 mushrooms (81.2%) in Kawauchi Village in Fukushima. They calculated committed effective doses based

Fig 5. Number of radioactive mushrooms detected. Mushroom activity was higher in areas with a high external gamma dose rate.

https://doi.org/10.1371/journal.pone.0174549.g005

Table 5. Results of questionnaire for 34 residents with detected radioactivity in fiscal 2013.

|                | very conscious | conscious | moderate | did not care | not care at all | total |
|----------------|----------------|-----------|----------|--------------|----------------|-------|
| water          | 5              | 11        | 0        | 15           | 3              | 34    |
| rice           | 3              | 9         | 0        | 17           | 5              | 34    |
| meat           | 1              | 11        | 0        | 17           | 5              | 34    |
| fish           | 3              | 9         | 0        | 17           | 5              | 34    |
| vegetable and fruit | 5          | 10        | 0        | 17           | 2              | 34    |
| mushroom       | 5              | 10        | 0        | 17           | 2              | 34    |
| milk           | 1              | 11        | 0        | 16           | 6              | 34    |
| dust<sup>a</sup> | 3            | 11        | 1        | 16           | 3              | 34    |
| during commute<sup>b</sup> | 3          | 7         | 0        | 15           | 3              | 28    |
| at work<sup>c</sup> | 3            | 10        | 0        | 18           | 2              | 33    |

<sup>a</sup> The number of persons who were concerned about radiation exposure from breathing dust.
<sup>b</sup> The number of persons who were concerned about radiation exposure during their commute.
<sup>c</sup> The number of persons who were concerned about radiation exposure at work.

https://doi.org/10.1371/journal.pone.0174549.t005
on 6,278 g per year of mushrooms per year, the average intake of Japanese citizens (age > 20 years, 17.2 g/day), ranging from doses of 0.11–1.60 mSv. [19]. In our study, some mushrooms from areas with a high external gamma dose rate were tested. The residents of this region were accustomed to eating wild plants with foraging being one of the favorite pastimes of the elderly. This study is a observational study, and though we cannot say for sure, we feel that the elderly eat wild plants in moderation while inspecting the food products and trying to enjoy life. Therefore, we will continue to work for raising awareness of radiation and its potential presence in food products and thus the continuing necessity of monitoring radioactivity in food in the future.

In conclusion, the committed effective dose for internal exposure to Cs for residents was, on an average, 1 μSv. The average for the residents with detectable radioactivity was 25 μSv, and the human health effects are considered to be extremely low risk. While trend of decreasing radioactivity has been observed in the food items brought in for inspection, but even now, food items such as mushrooms show a high level of radioactivity. WBC testing and food inspection should continue in the future in order to monitor radioactivity of residents in Namie.

**Supporting information**

S1 Table. Measurement result of WBC.

(DOCX)

S2 Table. Radioactivity Measurements of food.

(DOCX)

**Acknowledgments**

This work was supported by Research on the Health Effects of Radiation organized by Ministry of the Environment, Japan.

**Author Contributions**

Conceptualization: YH Y. Nishizawa.

Data curation: KN.

Formal analysis: ET.

Funding acquisition: Y. Nishizawa.

Investigation: YH KN.

Methodology: YH.

Project administration: YH.

Resources: YH.

Software: KN ET.

Supervision: KK.

Validation: Y. Noto.

Visualization: KN.

Writing – original draft: YH.
References

1. Hosoda M, Tokonami S, Akiba S, Kurihara O, Sorimachi A, Ishikawa T, et al. Estimation of internal exposure of the thyroid to (131)I on the basis of (134)Cs accumulated in the body among evacuees of the Fukushima Daiichi Nuclear Power Station accident. Environ Int. 2013 Nov; 61:73–6. https://doi.org/10.1016/j.envint.2013.09.013 PMID: 24103348

2. Hosoda M, Tokonami S, Omori Y, Ishikawa T, Iwaoa K. A comparison of the dose from natural radionuclides and artificial radionuclides after the Fukushima nuclear accident. J Radiat Res. 2016 Jul; 57(4):422–30. https://doi.org/10.1093/jrr/rrv102 PMID: 26838130

3. Tokonami S, Hosoda M, Akiba S, Sorimachi A, Kashiwakura I, Balonov M. Thyroid doses for evacuees from the Fukushima nuclear accident. Sci Rep. 2012; 2:507. https://doi.org/10.1038/srep00507 PMID: 22792439

4. Hosokawa Y, Hosoda M, Nakata A, Kon M, Urushizaka M, Yoshida M. Thyroid screening survey on children after Fukushima Daiichi Nuclear Power Plant accident. Radiat Emerg Med 2013; 2(1):82–6.

5. Watanobe H, Furutani T, Nihei M, Sakuma Y, Kado T, Matsuda N, et al. Internal radiation exposure dose in Iwaki city, Fukushima prefecture after the accident at Fukushima Daiichi Nuclear Power Plant. PLoS One. 2014 Dec 5; 9(12):e114407. https://doi.org/10.1371/journal.pone.0114407 PMID: 25478794

6. Merz S, Shozugawa K, Steinhauser G. Analysis of Japanese radionuclide monitoring data of food before and after the Fukushima nuclear accident. Environ Sci Technol. 2015 Mar 3; 49(5):2875–85. https://doi.org/10.1021/es5057648 PMID: 25621976

7. Soskova M, Kato S, Nomura S, Gilonov I, Novikova S, et al. Reduction of high levels of internal contamination by dietary intervention in residents of areas affected by the Fukushima Daiichi nuclear power plant disaster: a case series. PLoS One. 2014 Jun 16; 9(6):e100302. https://doi.org/10.1371/journal.pone.0100302 PMID: 24932486

8. Bernhardsson C, Vznova I, Råäf C, Mattsson S. Measurements of long-term external and internal radiation exposure of inhabitants of some villages of the Bryansk region of Russia after the Chernobyl accident. Sci Total Environ. 2011 Oct 15; 409(22):4811–7. https://doi.org/10.1016/j.scitotenv.2011.07.066 PMID: 21906781

9. Hoshi M, Konstantinov YO, Evdovee TY, Kovalev AI, Aksenov AS, Koulkova NV et al. Radionuclides in children residing in the western districts of the Bryansk Oblast from 1991–1996. Health Phys. 2000 Aug; 79(2):182–6. PMID: 10910388

10. McKee SA, O’Malley SS, Salovey P, Krishnan Sarin S, Mazure CM. Perceived risks and benefits of smoking cessation: gender-specific predictors of motivation and treatment outcome. Addict Behav. 2005 Mar; 30(3):423–35. https://doi.org/10.1016/j.addbeh.2004.05.027 PMID: 15718060

11. Toll BA, Salovey P, O’Malley SS, Mazure CM Latimer A, McKee SA. Message framing for smoking cessation: the interaction of risk perceptions and gender. Nicotine Tob Res. 2008 Jan; 10(1):195–200. https://doi.org/10.1080/14622200701767803 PMID: 18188760

12. McKee SA, O’Malley SS, Salovey P, Krishnan-Sarin S, Mazure CM. Perceived risks and benefits of smoking cessation: gender-specific predictors of motivation and treatment outcome. Addict Behav. 2005 Mar; 30(3):423–35. https://doi.org/10.1016/j.addbeh.2004.05.027 PMID: 15718060

13. Toll BA, Salovey P, O’Malley SS, Mazure CM Latimer A, McKee SA. Message framing for smoking cessation: the interaction of risk perceptions and gender. Nicotine Tob Res. 2008 Jan; 10(1):195–200. https://doi.org/10.1080/14622200701767803 PMID: 18188760

14. Consumer Affairs Agency, Government of Japan, Food and radiation Q&A (Eighth Edition) 2013 Sep 2, (Eighth Edition) [cited 10 November 2016]. In: Fukushima Revitalization Station web site [Internet]. Source: “Food and Radiation Q&A,” issued by the Consumer Affairs Agency—[PDF file] Available from http://www.caa.go.jp/jsirv/pdf/160315_food_qa.pdf
18. Travnikova IG, Bruk GJ, Shutov VN, Bazjukin AB, Balonov MI, Rahola T, et al. Contribution of different foodstuffs to the internal exposure of rural inhabitants. Radiation Protection Dosimetry 93:331–339, 2001. PMID: 11548360

19. Nakashima K, Orita M, Fukuda N, Taira Y, Hayashida N, Matsuda N, et al. Radiocesium concentrations in wild mushrooms collected in Kawauchi Village after the accident at the Fukushima Daiichi Nuclear Power Plant. PeerJ. 2015 Nov 24; 3:e1427. https://doi.org/10.7717/peerj.1427 PMID: 26623189