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Screening test for radioactivity of self-consumption products in Fukushima after the Fukushima Dai-ichi NPP accident in Japan

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ABSTRACT

A food inspection service system for home grown products or wild plants collected by individual consumers for self-consumption was implemented in Fukushima in Nov. 2012. About 500 NaI(Tl) scintillation spectrometers were distributed to 300 or more temporary testing laboratories which were set up in public halls or meeting places of the municipalities. The screening method for radiocaesium was adapted to the present inspection service system. The performance of the equipment under field conditions was evaluated using sampled data obtained by temporary testing laboratories. From the present results of evaluation the confidence of these inspections was confirmed. Totally about 550,000 food samples have been tested with a pass rate of 90% or more.

1. Introduction

Among 6 reactors sited in Fukushima Dai-ichi Nuclear Power Plant (NPP), 4 reactors were seriously damaged due to a huge earthquake and seawater flooding caused by a subsequent tidal wave "tsunami" in 2011. In consequence, large amounts of radioactive materials were released to the environment due to hydrogen explosions and damage of reactors. Among various kinds of radionuclides released from each reactor, most notable ones are ^{131}I, ^{134}Cs and ^{137}Cs for their activities and half-lives in case of the Fukushima accident. To deal with such an emergency situation, the Ministry of Health, Labour and Welfare (MHLW) in Japan implemented various regulations including indices for food and beverage intake restriction as provisional regulation values of radioactive materials in foods in accordance with the food sanitation act on 17th March 2011 (see Table 1) (MHLW, 2011a, b). Just after the accident, radioactivity contamination of foods and foodstuffs was due to mainly surface contamination of radioiodine. After around a few months, however, radiocaesium contamination in beef derived from intake of contaminated feed was detected. After this was revealed, pre-shipment inspection was required from the regulatory authority for all beef cattle. As a consequence the numbers of samples tested increased rapidly in September 2011. From that point, monitoring of radiocaesium went into high gear for not only beef but also other general foods. The radioactivity monitoring for legal inspection of foods and foodstuffs has been reinforced to ensure a sufficient supply of safe-to-eat foods. These legal actions apply to the inspection of radioactivity in foods and foodstuffs distributed through commercial markets and also to monitoring the radioactivity level of agricultural products grown in the areas where the distribution is restricted by the Japanese government. Furthermore Fukushima and other neighboring prefectural governments have promoted voluntary radioactivity inspections of foods and foodstuffs produced in each prefecture before shipment under the responsibility of individual producers in order to ensure the safety and reliability of their products.

On the other hand there was no sufficient inspection system for products cultivated in private vegetable gardens, wild plants or river/sea fishes collected by individual consumers for self-consumption. To deal with this, the Consumer Affairs Agency, the Fukushima prefectural government and the National Consumer Affairs Center of Japan have provided numerous NaI(Tl) scintillation spectrometers in public halls or meeting places of the municipalities for screening measurements of radioactivity in food collected by individual consumers for self-consumption.

In this paper the efforts for and impact on the food inspection system for home grown products or wild plants or fishes collected by individual consumers for self-consumption using a NaI(Tl) spectrometer

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Table 1
Provisional regulation values of radioactive materials in food in accordance with the food sanitation act (excerpted version). Standard values adapted from 1st Apr. 2012 are also shown.

	Provisional index value Radioactive Iodide[a] (Bq/kg)	**Provisional index value** Radio Caesium ^{134}Cs + ^{137}Cs (Bq/kg)	**Standard value (guideline value)** ^{134}Cs + ^{137}Cs (Bq/kg)
Drinking water	300	200	10
Milk	300[b]	200[b]	50
Foods for infants	–	–	50
Vegetables	2000	500	100
Food grain	2000	500	
Meat, Egg, Fish, others	2000	500	

[a] Representative radio-nuclides among mixed radio-nuclides: ^{131}I.
[b] Provide guidance so that materials exceeding 100 Bq/kg are not used in milk supplied for use in powdered baby formula or for direct drinking.

are outlined. The technical validation and effectiveness of this inspection service system are also discussed. Together with this experience, the applicability and usefulness of the screening method using a NaI(Tl) spectrometer are assessed with the results of the tests.

2. Radiocaesium screening method employed in Japan

In a nuclear emergency, it is essential to analyze rapidly radioactivity in samples from the environment and potentially contaminated foodstuffs and feed to protect workers and the public by keeping doses below the dose reference levels (ICRP, 2007). In the official radioactivity monitoring, γ-spectrometer using Ge-detector is the most powerful tool to determine the activity concentration of individual nuclides, and detectors are mostly installed and operated at testing laboratories for radioactivity analysis. However in an emergency situation too many samples should be measured with a limited number of Ge-detectors available.

In order to defuse such a situation, a specific technical guideline for screening of radiocaesium in foods/foodstuffs was issued by the MHLW (MHLW, 2011a, b). Such a screening approach based on rapid test methods helps the decision makers to decide whether activity concentrations in the samples are below the guideline value rapidly without any more sophisticated technique such as those using a high resolution Ge-detector. This screening method intends to use NaI(Tl) scintillation detectors as well as CsI and $LaBr_3$ scintillation detectors. Use of such a lower resolution detectors may be associated with some problems (e.g. spectrum deconvolution of doublet peaks, contribution from natural nuclides). Some improved peak analysis techniques might be expected to obtain more accurate results (Yamada and Takano, 2014). However accurate activity concentrations measurements of individual nuclides are not required on the screening approach, and an overestimation or larger uncertainty on the safe side can be allowed.

The present food inspection for radiocaesium in self-consumption products was designed to use NaI (Tl) scintillation spectrometers that may be easy to maintain since tests for inspection must be carried out at many "makeshift" places by personnel with little experience of radioactivity measurement. In addition in order to make it easy to decide activity concentrations in samples are above or below the guideline value, the screening method was adapted to the present self-consumption products inspection service system.

According to the guideline the following two performances are required:

$$C_{SL}^{\triangleright} = C_{SL} + t_{k-1,\alpha} \cdot u(C_{SL}) < C_{RL} \tag{1}$$

and $C_{SL} \geq$ Half of the guideline value,

$$c_A^* \leq \text{One-fourth of the guideline value,} \tag{2}$$

where t is the one sided t-distribution. In Eq. (1) $C_{SL}^{\triangleright}$ of upper limit of confidence interval of the best estimate of the true value for the screening level shall be below C_{RL} of the guideline value with a 99% confidence level. As for c_A^* of decision threshold in Eq. (2) 99.7% confidence level is required. As for the guideline value for general food, new limits were implemented in Japan on 1st Apr. 2012 that were based on 1 mSv a year consistent with an intervention exemption level adopted by Codex. The revised value are also shown in Table 1. Thus the guideline for screening was also adapted 50 Bq/kg or more of screening level C_{SL} for 100 Bq/kg of new guideline value in general foods.

3. Type testing of instrument for the screening

The performance-type-tests were carried out in accordance with a specific technical guideline for screening of radiocaesium in foods/foodstuffs using a NaI(Tl) γ-spectrometer issued by the MHLW. Six different models of spectrometer were mainly employed for food inspection of self-consumption products in Fukushima. In order to confirm the performance as required by the guideline, type tests were performed by the manufacturers themselves in advance before shipment. The purpose of this method is to make it possible to judge samples below the screening level value as "negative" (not exceed the guideline value) at a 99% confidence level.

The screening level shall be set at 50 Bq/kg or more for 100 Bq/kg limit in general foods. To ensure the 99% confidence level for the screening level, a reference material having 50 Bq/kg or more was measured more than once, preferably more than 5 times reproducibly, and the mean value C_{SL} and its standard deviation u_{SL} were determined. Employing t-distribution for $C_{SL}^{\triangleright}$ might be evaluated as the safest side. The result was compared to the calculated C_{RL}, equivalent to 100 Bq/kg, which was obtained by measurement using a reference source of ^{134}Cs and/or ^{137}Cs. The Japan Radioisotope Association asked manufacturers of instruments for submission of these data to provide reliable information about equipment for radioactivity measurement to users as checking data. A summary of the results of measurements and calculations for 6 models of equipment are shown in Table 2. Every $C_{SL} + t_{k-1,\alpha} \cdot u(C_{SL})$ obtained from the reference material having the screening level for the present six types of equipment was below the guideline value. These results denote that these 6 models of equipment employed for radiocaesium screening for home grown products or wild plants collected by individual consumers complied in accordance with the requirements in the guideline.

4. Validation of practical performances of apparatus in field conditions

In Fukushima prefecture, around 500 sets of equipment were installed in about 300 temporary testing laboratories as was already mentioned. Environmental test conditions including the ambient dose rate at inside and outside the laboratories were checked by trained personnel before starting the sample measurement service. Measured ambient dose rates at the outside of the 54 sampled laboratories are shown on the map (Fig. 1). As shown in this figure, almost all laboratories are set at the places where ambient dose rate levels are significantly higher than standard conditions. Measured ambient dose rates at the inside of laboratories are shown in the graph of Fig. 2 with those at the outside. As shown in this graph dose rates at the inside of each laboratory were kept at 0.4 μSv/h or less in February 2012. While all models of equipment installed at laboratories complied with the requirements in the guideline as seen in Table 2, these performance tests were carried out under standard test conditions whose ambient dose rate level is around 0.1 μSv/h. Higher background dose rate in field conditions might affect the performance on screening. In order to