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RADIOACTIVE SUBSTANCES IN TAP WATER

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Abstract : A 9.0 magnitude (M) earthquake with an epicenter off the Sanriku coast occurred at 14 : 46 on March 11, 2011. TEPCO Fukushima Daiichi Nuclear Power Plant (F-1 NPP) was struck by the earthquake and its resulting tsunami. Consequently a critical nuclear disaster developed, as a large quantity of radioactive materials was released due to a hydrogen blast. On March 16th, 2011, radioiodine and radioactive cesium were detected at levels of 177 Bq/kg and 58 Bq/kg, respectively, in tap water in Fukushima city (about 62km northwest of TEPCO F-1 NPP). On March 20th, radioiodine was detected in tap water at a level of 965 Bq/kg, which is over the value-index of restrictions on food and drink intake (radioiodine 300 Bq/kg (infant intake 100 Bq/kg)) designated by the Nuclear Safety Commission. Therefore, intake restriction measures were taken regarding drinking water. After that, although the all intake restrictions were lifted, in order to confirm the safety of tap water, an inspection system was established to monitor all tap water in the prefecture. This system has confirmed that there has been no detection of radioiodine or radioactive cesium in tap water in the prefecture since May 5th, 2011. Furthermore, radioactive strontium (^{89}Sr, ^{90}Sr) and plutonium (^{238}Pu, ^{239}Pu+^{240}Pu) in tap water and the raw water supply were measured. As a result, ^{89}Sr, ^{238}Pu, ^{239}Pu+^{240}Pu were undetectable and although ^{90}Sr was detected, its committed effective dose of 0.00017 mSv was much lower than the yearly 0.1 mSv of the World Health Organization guidelines for drinking water quality. In addition, the results did not show any deviations from past inspection results.

Key words : Radioactive substances, Monitoring, Tap water

1. BACKGROUND OF THE NUCLEAR DISASTER

A 9.0 magnitude (M) earthquake with an epicenter off the Sanriku coast occurred at 14 : 46 on March 11, 2011. Tokyo Electric Power Company (TEPCO) Fukushima Daiichi Nuclear Power Plant (F-1 NPP) was struck by the earthquake and its resulting tsunami, which caused loss of power supply, thereby disabling the plant's ability to cool its reactors. A critical nuclear disaster developed at the plant after a hydrogen blast resulted in the release of a large quantity of radioactive materials. On March 12th, the mandatory evacuation of all residents within a 20km radius of the plant was ordered, and the voluntary evacuation of residents within a 30km radius was instituted on March 25th. On April 22nd, a 'planned evacuation zone' and an 'emergency evacuation preparation zone' were designated, along with the classification of the 20 km area as a 'restricted zone' with limited entrants into the area. At present, these zones have been revised, and rearranged into three zones ; 'zones being prepared for the lifting of the evacuation order', 'restricted zones of residency' and 'difficult-to-return zones', depending mainly on air radiation levels.

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2. THE TREND SURROUNDING DRINKING WATER AFTER THE DISASTER

1) Detection and correspondence for radioiodine and radioactive cesium in tap water

On March 16th, 2011, radioiodine and radioactive cesium were detected in tap water in Fukushima city at levels of 177 Bq/kg and 58 Bq/kg, respectively. At that time, the index-values for intake restriction of radioiodine and radioactive cesium in drinking water were 300 Bq/kg and 200 Bq/kg, respectively. However, on March 17th in Kawamata town, 47km northwest of TEPCO F-1 NPP, the levels of radioiodine were temporarily detected as 308 Bq/kg in tap water, exceeding the index-value. Furthermore, on March 20th in Iitate village, levels far exceeding the index-value were detected in tap water, at 965 Bq/kg. The water source for both Kawamata and Iitate is surface water. On March 21st, intake restriction measures were adopted, together with a notification from the Chief of Water Supply Services in the Health Sector of the Ministry of Health, Labor and Welfare, for infants not to drink tap water in cases where radioiodine had exceeded 100 Bq/kg. The following day, levels of radioiodine exceeding 100 Bq/kg were detected in 5 towns and cities other than Iitate village, and the appropriate measures were taken to restrict infant intake of tap water. After that, the radioiodine levels steadily decreased to below 100 Bq/kg in tap water within the prefecture. The restriction was lifted in the 5 towns and cities mentioned above on April 1st, and in Iitate village on May 10th, meaning that the restriction was lifted in all of Fukushima Prefecture. After May 5th, 2011, neither radioiodine nor radioactive cesium was detected in tap water within the prefecture.

2) Reasons for radioiodine and radioactive cesium not being detected in tap water within Fukushima Prefecture

It could be considered that radioactive substances fell with the rain into the rivers, which flowed through the water intake facilities. Added to the fact that radioiodine half-life is 8.02 days, this resulted in the decrease in the total amount over time. On the other hand, the radioactive cesium, a characteristic of which is its ability to adhere to substances such as soil, was released into the air by the accident and contaminated the water. It was then removed from the water through processes such as filtration, having settled on the riverbed after attaching itself to substances in turbid water.

3. PROVISION OF AN INSPECTION MONITORING SYSTEM

1) The start of inspection monitoring of tap water within the prefecture

Due to the detection of radioiodine and radioactive cesium in domestic water within Fukushima Prefecture, tap water inspection monitoring started on March 17th, 2011, targeting 7 locations throughout the prefecture. Analyzing all tap water in the prefecture was difficult, as the number of institutes available were limited. Moreover, these institutes also had to run tests for materials other than water. From March 21st, the number of locations was increased to 77 within the Nakadori and Hamadori areas, and 159 in the Aizu area. Due to these large numbers, non-governmental institutions were brought in to assist at this point. All inspections were arranged into a single tap water monitoring system for the whole of the prefecture from April 6th, which set the frequency to every day for intake restricted zones. The remaining regions were divided into 3 areas according to their topography, and were monitored at frequencies between every 2 days and every 5 days.

2) Deployment of monitoring inspection equipment

In cases where the inspections were partially confined to nongovernmental institutions, some results were delayed by a few days due to situations such as having to send samples via long distance transportation. Thus, in order to shorten the time taken to receive results by as much as possible, a system was designed to inspect all tap water within Fukushima Prefecture. This system included sending a Ge semiconductor detector, as drinking water inspection equipment, to prefectural institutes and prefectural water suppliers. As a result, 6 detectors were sent to 6 locations between September and October 2011, and 7 detectors were sent to a further 5 locations in September and October 2012. At present, 14 detectors are being used to analyze tap water, well water for drinking, etc., throughout the whole prefecture.

3) Establishment of the monitoring inspection system

In October 2011, a "radioactive substances monitoring execution plan" was established together with the deployment of the monitoring equipment throughout the prefecture. This plan set the frequency of inspection to between once a month and three times a week for all tap water, based on the

distance from F-1 NPP and air radiation levels. In addition, currently, the frequency of inspections etc. are being revised and will implemented based on this plan.

4) Measurement of radioactive strontium and plutonium in tap water and raw water for water supply

(1) Objectives for measurement

Currently, a "controlled desired index pertaining to radioactive substances in tap water" exists for radioactive cesium (^{134}Cs ^{137}Cs) only, at 10 Bq/kg. The reasoning for this is as follows : although it is possible to monitor radionuclides such as radioactive strontium (^{89}Sr, ^{90}Sr) and plutonium (^{238}Pu, ^{239}Pu+^{240}Pu), the highest concentration of any of these, ^{90}Sr, is only 2% of that of ^{137}Cs. Therefore, monitoring radioactive cesium alone enables the monitoring of these radionuclides. However, not only Fukushima residents, but also people inside and outside Japan have shown marked interest in the influence of radioactive strontium and plutonium, as a result of the accident. This is because radioactive strontium behaves in a similar manner to calcium inside the body, as well as the fact that it has been reported in the media that plutonium can cause cancer. Thus, as knowledge of radioactive strontium and plutonium levels is limited, research into the levels of these radionuclides in the raw water supply has started. On the other hand, research into radioactive cesium is ongoing.

(2) Measurement

Measurements were taken from tap water and the raw water supply at 2 and 20 locations, respectively, throughout the prefecture. The ion-exchange method outlined by the Ministry of Education, Culture, Sports, Science and Technology (MEXT) in "Radioactive strontium analysis" (revised in 2003) was used to measure strontium with background beta ray measurement equipment. Regarding measurement of plutonium, the ion-exchange method outlined in MEXT's "Plutonium analysis" (revised in 1990) was employed, using a silicon semiconductor detector.

(3) Results

In the raw water supply, ^{90}Sr was detected at all locations, at measurements ranging from 0.0005-0.0028 Bq/L. ^{90}Sr was also detected at both tap water locations, ranging from 0.0013-0.0014 Bq/L. However, ^{89}Sr and plutonium (^{238}Pu, ^{239}Pu+^{240}Pu) levels were lower than their detection limits, with averages of 0.002 Bq/L and 0.00001 Bq/L, respectively.

(4) Evaluation

(i) Committed effective dose

The detected concentrations of ^{90}Sr were within the nationwide data range before the accident (no detection-0.017 Bq/L for the raw water supply, and no detection-0.0039 Bq/L for tap water).

In cases where water containing detected concentrations of ^{90}Sr (0.0028 Bq/L) is drunk for one year, the following equations are used to calculate the body's committed effective dose and yearly radionuclide intake, respectively.

Table 1. Comparison of inspection result and past nationwide data

Category	Classification	Inspection results of this study [Bq/L]	(Reference) Past nationwide data [Bq/L]
Sr-90	Tap water (2 locations)	0.0013-0.0014	Undetectable-0.0039 (*1)
	Raw water supply (20 locations)	0.0005-0.0028	Undetectable-0.017 (*2)
Sr-89	Tap water (2 points)	Undetectable	---
	Raw water supply (20 locations)	Undetectable	---

Table 2. Committed effective dose of ^{90}Sr and calculation method

Age	^{90}Sr Effective dose coefficient [Sv/Bq]	Tap water intake amount [L/day]	Committed effective dose [mSv]
Infants (3 months)	2.30E-07	0.71	0.00017
Children (12 months)	7.30E-08	1	0.000075
Adults (over 16 years old)	2.80E08	1.65	0.000047

Fig. 1. Progression of ^{90}Sr concentrations in tap water in Fukushima city.

Committed effective dose [mSv]=effective dose coefficient [mSv/Bq]×yearly radionuclide intake amount [Bq/year]×market dilution factor x reduction corrections for factors such as cooking.

Yearly radionuclide intake amount=result of inspection [Bq/L]×intake amount per day depending on age [L/day]×365 [day/year]

The market dilution factor and reduction corrections are set as 1 and calculated since neither are expected.

The highest committed effective dose was found in infants aged 3 months, at 0.000 17 mSv, which is a very small amount compared with the yearly limit of 0.1 mSv, as outlined by the World Health Organization guidelines for drinking-water quality.

(ii) Comparison of the current measurement results with previous measurement results

One of the inspected locations of tap water, in Fukushima city, has had its ^{90}Sr levels periodically surveyed since the 1970's due to an environmental radioactivity standard survey, which was required of all prefectures originally by MEXT, and is currently required by the Nuclear Regulatory Agency. Fig. 1 shows the comparison between current measurement results and past survey results (reference : Nuclear Regulatory Agency "Environmental radioactivity database" http://search.kankyo-hoshano.go.jp/servlet/search.top,(reference 2013-10-17)). In the 1950's to 1960's, atmospheric nuclear tests were frequently performed all over the world, resulting in significant amounts of ^{90}Sr being released into the atmosphere. Levels of ^{90}Sr remain in the air, but have gradually decreased in the absence of these tests. (Meteorological Research Institute, Geochemical Research department ; Geoscience research and analysis method for artificial radionuclides of precipitation/falling dusts ; Meteorological Research Institute technical report No. 36 1996.12). The results of the measurements taken at all 22 raw water and tap water locations in Fukushima Prefecture show that, regarding tap water, the amount of ^{90}Sr released as a result of the TEPCO F-1 NPP accident was lower than previously recorded amounts, which are subject to fluctuations.

(5) Future monitoring inspection

To use tap water without anxiety, the present monitoring system will be kept for radioiodine and radioactive cesium. Furthermore, for the residents of the evacuation order zones to return home without anxiety, inspection of well water is planned in cooperating cities, towns and villages of such zones. In addition, a periodic inspection will be held for plutonium and radioactive strontium, to decrease the anxiety of the residents of Fukushima Prefecture.

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