Monitoring dissolved radioactive cesium in Abukuma River in Fukushima Prefecture

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Radioactive materials were released into the atmosphere and deposited over wide areas of farmland, forests, and cities; elevated levels of ^{131}I, ^{134}Cs, and ^{137}Cs have been detected in these areas due to the accident at the Tokyo Power Fukushima Daiichi Nuclear Power Plant caused by the April 2011 earthquake and tsunami in eastern Japan. Radioactive Cs deposited on farmland and forests gradually leaches into water bodies such as mountain streams and rivers adsorbed onto particles or in a dissolved state. It is important to calrify the level of dissolved and total radioactive Cs in environmental water for forecasting the of discharge of radioactive Cs from forest and watersheds, assessing on the effect of dissolved and total radioactive Cs on not only irrigation water but also rice and other crops, and evaluating the transport of radioactive Cs from rivers to costal areas. Therefore, it is important to monitor their levels in Fukushima Prefecture over time. In this research, we monitored the levels of dissolved and total radioactive Cs in Abukuma River using a conventional evaporative concentration method. By monitoring the river waters since September 2012, it was estimated that the levels of dissolved radioactive Cs were less than 0.128 Bq/L and those of total radioactive Cs were less than 0.274 Bq/L in the main stream and branches of Abukuma River in the low suspended solid condition.

Key Words: *Dissolved radioactive cesium, River water, Fukushima, Abukuma River*

1. Introduction

Radioactive materials were released into the atmosphere and deposited over wide areas of farmland, forests, and urban areas in Kanto district; elevated levels of ^{131}I, ^{134}Cs, and ^{137}Cs have been detected in these areas due to the accident at the Tokyo Power Fukushima Daiichi Nuclear Power Plant following the March 2011 earthquake and tsunami in eastern Japan[1)]. Radioactive Cs deposited on farmland and forests gradually leaches into water bodies such as mountain streams and rivers adsorbed onto particles or in a dissolved state.

It is important to calrify the level of dissolved and total radioactive Cs in environmental water for forecasting the of discharge of radioactive Cs from forest and watersheds, assessing on the effect of dissolved and total radioactive Cs on not only irrigation water but also rice and other crops, and evaluating the transport of radioactive Cs from rivers to costal areas.

Therefore, it is important to monitor its level in Fukushima Prefecture over time. However, the levelof dissolved radioactive Cs in Fukushima Prefecture is less than 0.5 Bq/L. It is too low to analyze using a 2-L Marinelli container with a germanium semiconductor detector.

Before the nuclear power plant accident, levels of radioactive substances in the rivers of Japan were very low (total, 0.063–1.89 mBq/L; particulate, 0.037 –0.50

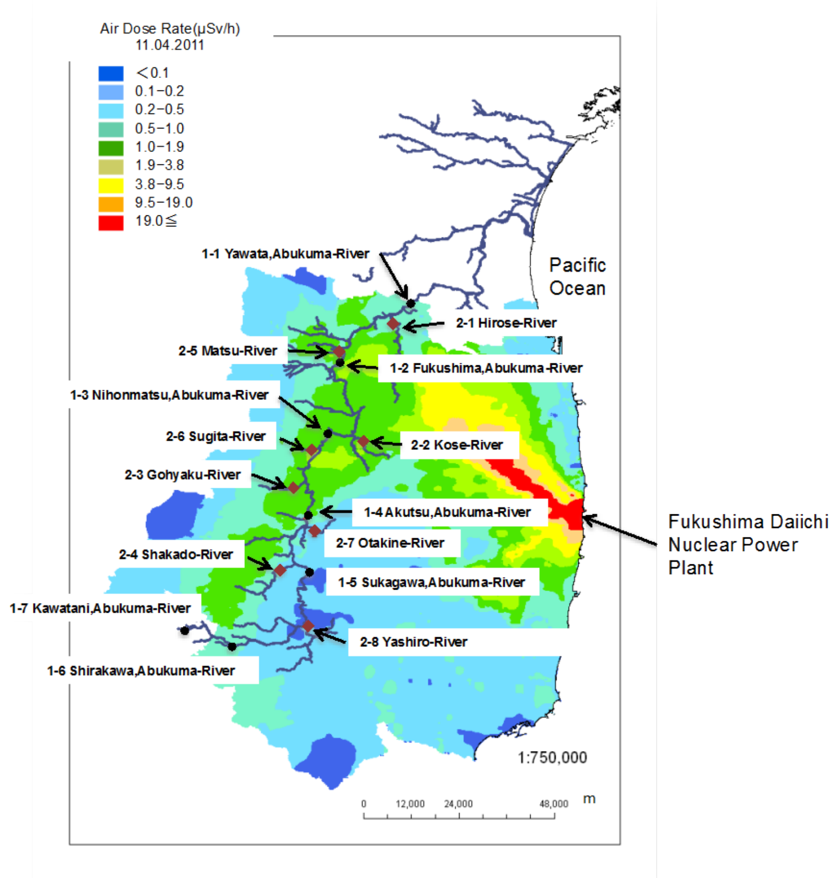

Figure 1 Sampling points

mBq/L).[2] After the accident, average levels of 0.54 Bq/L ^{134}Cs and 0.58 Bq/L ^{137}Cs were measured in 51 rivers in Fukushima Prefecture, including Cs both adsorbed onto particles and in a dissolved state[3]. However, there are few other studies of radioactive Cs levels in particulate and dissolved states after the accident other than one investigation of the Pacific coast[4].

In this research, we monitored the levels of dissolved radioactive Cs in Abukuma River using a traditional evaporative concentration method.

2. Material and Methods

(1) Sampling information

River-water samples (30 or 40 L) were collected at 7 different sampling points along the main stream of Abukuma River and 8 different sampling points in the branches of Abukuma River within Fukushima Prefecture. Figure 1 shows the sampling points. Water sampling was conducted in the field on September 14 and 15, 2012, which was at least 3 days later after the rainfall.

(2) Preconcentration and analysis

Existing methods for analysis of low concentrations of dissolved radioactive Cs include the evaporative concentration method[5], coprecipitation with ammonium phosphomolybdate[6], ion exchange analysis[7], and solid phase extraction disks containing cobalt ferrocyanide (KCFC), which specifically select for Cs[8]. In this research, we used a conventional evaporative concentration method.

The field-collected water samples were passed through a 0.45-μm membrane filter to remove suspended materials. The filtrates were then condenseded from 30 or 40 L to 2 L by a solvent evaporation method. The levels of radioactive Cs in the river water samples were measured using gamma-ray spectrometry with a Ge semiconductor detector (SEG-EMS GEM20-70; Seiko EG&G Co., Ltd., Tokyo, Japan). The measurement time was 43,200 s (12 h) for each sample.

In addition, total level of radioactive Cs in water was determined by summing radioactive Cs on the 0.45 - μm membrane filter anddissolved radioactive Cs in water.

Table 1 Dissolved and total radioactive cesium in the main stream of Abukuma River

Sampling Information						Dissolved Radioactive Cesium Cocentration (Bq/L)**			Total Radioactive Cesium Cocentration (Bq/L)**			Dissolved Cs / Tota Cs
Sampling point		Latitude	Longitude	Air Dose Rate* (μSv/h)	Date	^{134}Cs	^{137}Cs	TOTAL	^{134}Cs	^{137}Cs	TOTAL	
1-1	Yahata	37.892778	140.643611	0.6	9/14/12	0.024	0.044	0.068	0.099	0.170	0.270	24%
1-2	Fukushima	37.758844	140.487369	2	9/14/12	0.014	0.026	0.040	0.095	0.152	0.247	15%
1-3	Nihonmatsu	37.594033	140.461281	1.8	9/14/12	0.011	0.025	0.036	0.064	0.111	0.175	18%
1-4	Akutsu	37.407983	140.408708	1	9/15/12	0.013	0.027	0.040	0.044	0.079	0.123	29%
1-5	Sukagawa	37.287222	140.413333	0.35	9/14/12	0.007	0.010	0.017	0.013	0.018	0.031	54%
1-6	Shirakawa	37.116667	140.244722	0.6	9/14/12	0.008	0.014	0.022	0.022	0.038	0.060	35%
1-7	Kawatani	37.147778	140.136111	0.3	9/14/12	<0.005	<0.005	<0.010	<0.007	<0.006	<0.013	-

*Air dose rate was estimated using the MEXT (2011) [1)]

**Radioactive cesium concentration was corrected to the concentration of the samples days and error of measurement are 1% - 29%.

Table 2 Dissolved and total radioactive cesium in the branches of Abukuma River

Sampling Information						Dissolved Radioactive Cesium Cocentration (Bq/L)**			Total Radioactive Cesium Cocentration (Bq/L)**			Dissolved Cs / Tota Cs
Sampling point		Latitude	Longitude	Air Dose Rate* (μSv/h)	Date	^{134}Cs	^{137}Cs	TOTAL	^{134}Cs	^{137}Cs	TOTAL	
2-1	Hirose-river	37.853322	140.609767	0.9	9/14/12	0.011	0.019	0.030	0.041	0.070	0.111	26%
2-2	Kose-River	37.580981	140.541906	2	9/14/12	<0.004	<0.006	<0.010	0.076	0.126	0.202	-
2-3	Gohyaku-River	37.483289	140.399556	1.1	9/15/12	0.011	0.022	0.033	0.103	0.171	0.274	11%
2-4	Shakado-River	37.288633	140.354719	0.35	9/14/12	0.007	0.013	0.020	0.019	0.034	0.053	40%
2-5	Matsu-River	37.778000	140.485000	1.5	9/14/12	0.043	0.083	0.128	0.051	0.096	0.147	84%
2-6	Sugita-River	37.561736	140.426286	1.9	9/14/12	0.011	0.025	0.036	0.053	0.096	0.149	21%
2-7	Otakine-River	37.370178	140.428678	0.35	9/15/12	0.005	0.009	0.014	0.012	0.020	0.032	42%
2-8	Yashiro-River	37.167225	140.409737	0.15	9/14/12	0.009	0.016	0.025	0.014	0.029	0.043	65%

*Air dose rate was estimated using the MEXT (2011) [1)]

**Radioactive cesium concentration was corrected to the concentration of the samples days and error of measurement are 1% - 29%.

3. Results

Tables 1 and 2 show the levels of dissolved and total radioactive Cs in Abukuma River. The level of SS in river water is extremely low (from 0.5 mg/L to 11 mg/L) because sampling day was at least 3 days later after the rainfall.

The levels of dissolved radioactive Cs and total radioactive Cs were confirmed to be low both in the sampling points 1-1 through 1-7 located in the Abukuma main channel and at the sampling points 2-1 through 2-7 located in the branches of Abukuma River. The levels of radioactive Cs were less than 0.128 Bq/L and those of total radioactive cesium were less than 0.274 Bq/L.

The level of dissolved radioactive Cs was less than 0.010 Bq/L at Kawatari point 1-7 located in the uppermost stream of Abukuma River. We think that the low disposition of radioactive Cs at Kawatani sampling point (compared to the air dose of radioactivity: see Fig. 1) is attributed to little inflow from other rivers and little human activity. In the case of 2 sample points 1-5 (Sukagawa) and 1-6 (Shirakawa) which are located upstream from the main channel of Abukuma River, the levels of dissolved radioactive Cs were in the range of 0.017–0.022 Bq/L and those of total radioactive cesium were in the range of 0.031- 0.060 Bq/L. In spite of the small Cs disposition, these values revealed a high tendency compared with samples from point 1-7 (Kawatani) located in the uppermost channel of Abukuma River.

Furthermore, much higher levels of dissolved radioactive cesium were observed at sampling points 1-2, 1-3, and 1-4 located downstream which were in the range of 0.036 – 0.040 Bq/L. The levels of total radioactive cesium showed radioactivity in the range of 0.123 – 0.147 Bq/L. An increase of dissolved radioactive Cs was likely due to a high disposition dose in this region.

Moreover, the levels of dissolved radioactive Cs and total radioactive Cs at the sampling point 1-1, which located farthest downstream, presented higher radioactivity than at other sampling points in the main stream of Abukuma River. The influence of both the inflow of other rivers such as the Hirose River and the Matsu River, where high deposition of radioactive Cs occurred, and the inflow from sampling point 1-2 located in the upper main channel of Abukuma River can be taken into consideration.

Finally, the level of dissolved radioactive Cs was over 0.03 Bq/L at sampling points 2-1, 2-3, 2-5, and 2-6, where river waters with high deposition radioactive Cs flow. It was confirmed that the values in these branches were higher than those in any other branches of Abukuma River.

4. Conclusions

In the present study, dissolved radioactive Cs levels in water samples collected from Abukuma River in September 2012 were less than 0.128 Bq/L and total radioactive Cs levels of these samples were less than 0.274 Bq/L in low SS condition. These values were verified to be 1/100–1/1000 of the index value (10 Bq/L) set for radioactive Cs in drinking water according to the quality standards. Further continuous monitoring will be carried out in the near future.

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References

1) Ministry of Education, C., Sports, Science and Technology in Japan: Results of the Fourth Airborne Monitoring Survey by MEXT(December 16, 2011). 2011
2) Hirose, K., M. Aoyama,Y. Sugimura: Plutonium and cesium isotopes in river waters in Japan. Journal Of Radioanalytical and Nuclear Chemistry, **141**, 191–202, 1990
3) Ministry of Education, C., Sports, Science and Technology in Japan: Monitoring Information of Environmental Radioactivity Level. 2012
4) Inoue, M., H. Kofuji, Y. Hamajima, S. Nagao, K. Yoshida,M. Yamamoto: ^{134}Cs and ^{137}Cs activities in coastal seawater along Northern Sanriku and Tsugaru Strait, northeastern Japan, after Fukushima Dai-ichi Nuclear Power Plant accident. Journal of Environmental Radioactivity, **111**, 116–119, 2012
5) Ministry of Education, C., Sports, Science and Technology in Japan: Radioactivity Measurement. In: Series No. 13: Japan Chemical Analysis Center, Chiba (in Japanese). 1982
6) Aoyama, M., K. Hirose, T. Miyao,Y. Igarashi: Low level 137Cs measurements in deep seawater samples. Appl. Radiat. Isot. , **53**, 159–162, 2000
7) Boni, A.L.: Rapid Ion Exchage Analysis of Radiocesium in Milk, Urine, Sea Water, and Enviromental Samples. Analytical Chemistry, **38**, 89–92, 1966
8) Beals, D.M., W.G. Britt, J.P. Bibler, D.A. Brooks: Radionuclide analysis using solid phase extraction disks. Journal of Radioanalytical and Nuclear Chemistry, **236**, 187–191, 1988