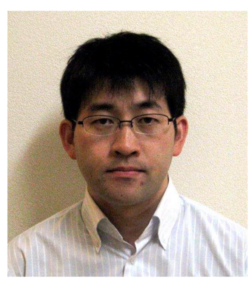
Influence of radioactive materials on treated water and dehydrated sludge cake at Sendai City Waterworks



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INTRODUCTION

The Great East Japan Earthquake, which occurred on March 11, 2011, caused serious damage to Fukushima Daiichi Nuclear Power Plant. Despite exhaustive efforts to handle the emergency situation, the cooling systems ceased functioning, resulting hydrogen explosions which destroyed the nuclear facilities. At the same time, large amounts of radioactive materials including iodine and cesium were released into the environment. After the explosions, radioactive iodine (^{131}I) and cesium (^{134}Cs and ^{137}Cs) were detected in drinking water (Ministry of Health, Labor and Welfare (MHLW), 2011[1]; Ikemoto and Magara, 2011[2]). Twenty water supply utilities implemented restrictions on tap water intake for infants from March 21 to May 10, 2011. Within the service area of Sendai City Waterworks, radioactive materials were detected in treated water and dehydrated sludge cake. It was suggested that the fluctuation in the concentration of radioactive materials was due to differences in sludge treatment methods, water source environments, and other factors. In this paper, we describe the influence of radioactive materials on treated water and dehydrated sludge cake at Sendai City Waterworks.

METHODS

Outline of water supply in Sendai City
Sendai City is located in the middle of Miyagi Prefecture in northeastern Japan (The Tohoku region). It is about 95km away from Fukushima Daiichi Nuclear Power Plant.

Table 1 – Basic data of Sendai City Waterworks (2013).

Beginning of supply	March, 1923
Service area	Approx. 359km^2
Population served	1,045,133 people
Distribution amount per day	361,606 m^3/day (Max.)
Water Purification plants (WPP)	4 main and 4 smaller plants
Reservoirs and Pumps	65 sites and 49 sites
Distribution pipelines	Approx. 3,386km
Number of the staff member	406

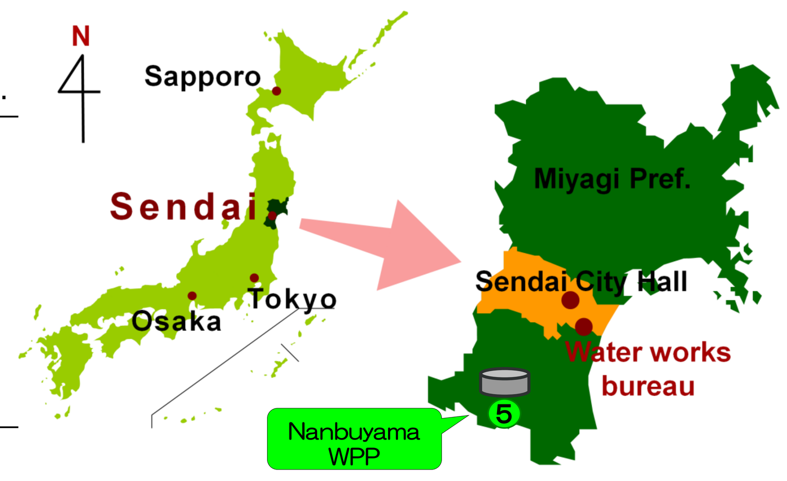

Figure 1 – Location of Sendai City.

Table 2 – Outline of major Water Purification plant (WPP).

WPP	capacity of facilities (m^3/day)	main water source	sludge treatment facilities
1 Moniwa	190,500	**direct** (Kamahusa dam)	sun drying
2 Kunimi	97,300	**discharge** (Okura dam)	sun drying
3 Nakahara	34,500	**discharge** (Okura dam)	sun drying
4 Fukuoka	60,600	**discharge** (Nanakita dam)	mechanical pressure
5 Nanbuyama*	279,000	**direct** (Shichikashuku dam)	mechanical pressure

Treatment method is coagulation and rapid sand filteration in these WPPs.
* Miyagi pref. (bulk water supply). It accounts for 1/3 of the total distribution amount in Sendai City Waterworks.

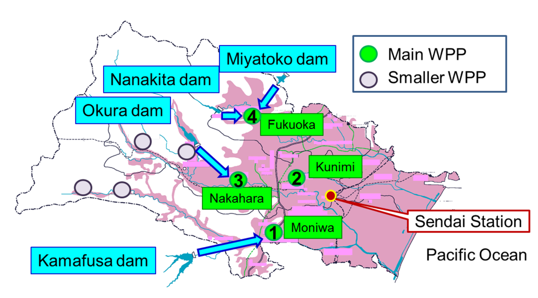

Figure 2 – Location of our WPP and water source.

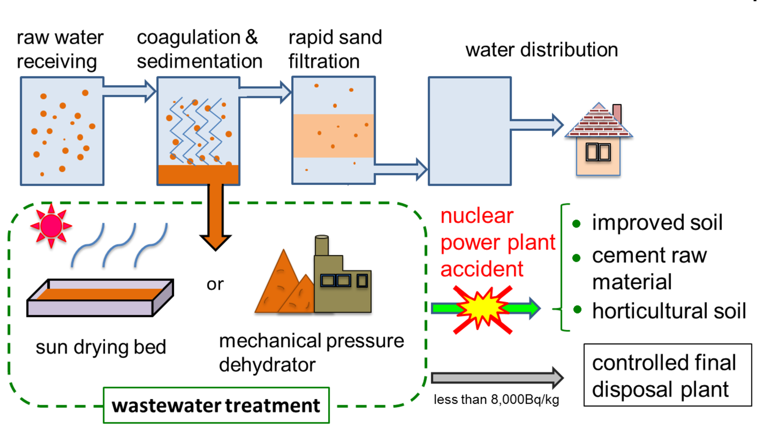

Figure 3 – Schematic flow in our WPP.

Table 3 – Index value of reusing dehydrated sludge cake.

application of reuse	index value
cement or concrete	below **100Bq/kg***1 (in finished product)
agricultural soil	below **400Bq/kg***1 (in finished product)
horticultural soil	below **400Bq/kg***3 (at time of removal from WPP)
ground soil	below **200Bq/kg***3 (at time of removal from WPP)

*1 Nuclear Reactor Regulation Law
*2 notice of Ministry of Agriculture, Forestry and Fishery
*3 notice of Ministry of Health, Labour and Welfare

Measurement of radioactive materials in treated water and dehydrated sludge cake
We started to measure concentrations of radioactive materials in treated water on March 24, 2011 and sludge cake on April 11, 2011. Radioactive iodine (^{131}I) and cesium (^{134}Cs and ^{137}Cs) contained in the samples were measured with a germanium semiconductor detector. The minimum detectable value of these radioactive materials in treated water is approximately 0.5Bq/kg. The samples of treated water were collected from 4 WPPs (Moniwa, Kunimi, Fukuoka, and Nanbuyama) once a week. We also collected samples of dehydrated sludge cake just after their being carried out from sun-drying beds or mechanical pressure dehydrators at those WPPs. The water content ratio of sludge from Moniwa and Fukuoka was about 67% and 77%, respectively. The drying period differs according to the method used (sun drying or mechanical pressure dehydration), so we compared the radioactive cesium level of dehydrated sludge cakes at the start of drying for each method (Fig. 7).

RESULTS - 1

1. Radioactive iodine and cesium in treated water
The maximum concentrations of radioactive iodine and cesium were detected on March 30 (6.5Bq/kg) and May 11 (1.4Bq/kg), 2011, respectively. These results were much lower than the hazard index levels (radioactive iodine: 300Bq/kg (100Bq/kg for infants), radioactive cesium: 200Bq/kg) which set by the MHLW on March 19 and March 21, 2011. Radioactive iodine was detected before radioactive cesium.

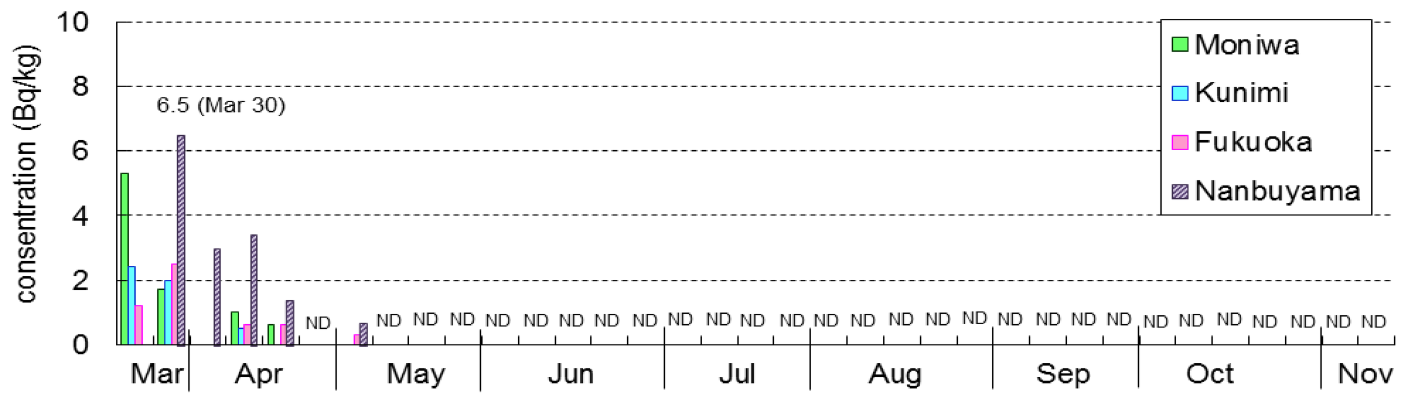

Figure 4 – Measurement result of ^{131}I from March to November 2011.

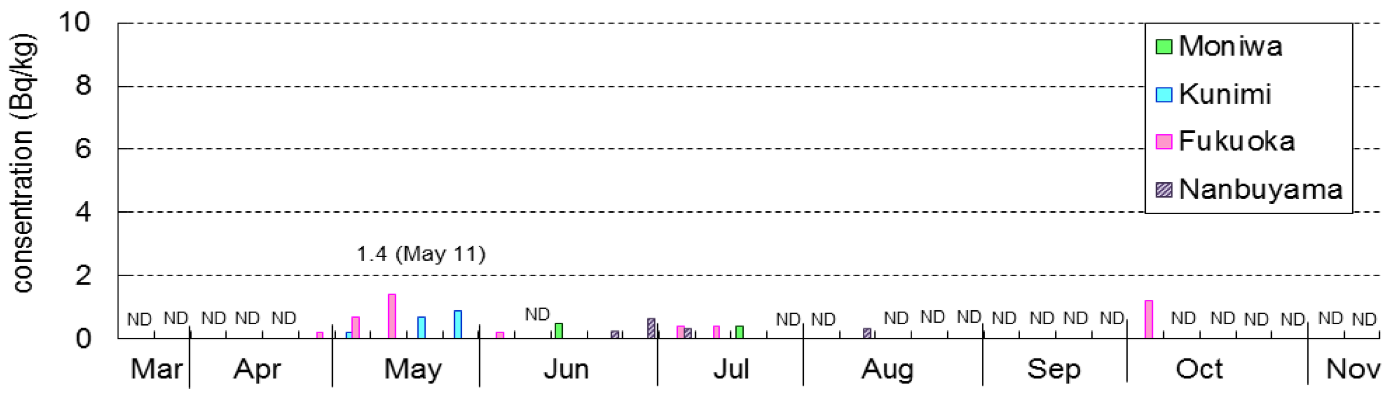

Figure 5 – Measurement result of ^{134}Cs and ^{137}Cs from March to November 2011.

RESULTS - 2

2. Radioactive cesium in dehydrated sludge cake

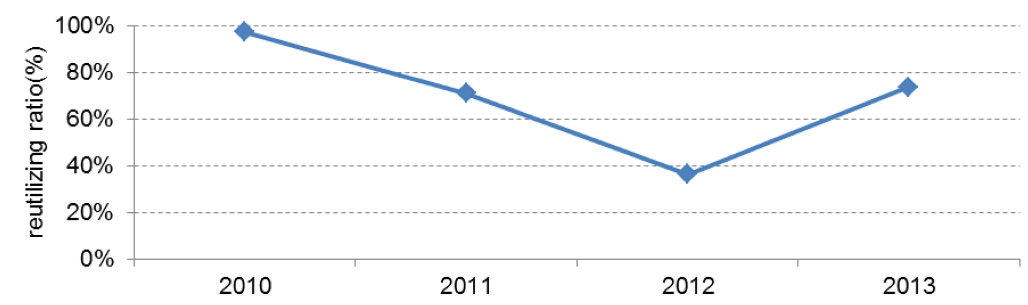

Fig. 6 shows that the reutilization ratio of dehydrated sludge cake decreased considerably from 97.3% in 2010 to 36.2% in 2012.

Figure 6 – Reutilization ratio of dehydrated sludge cake in Sendai City Waterworks.

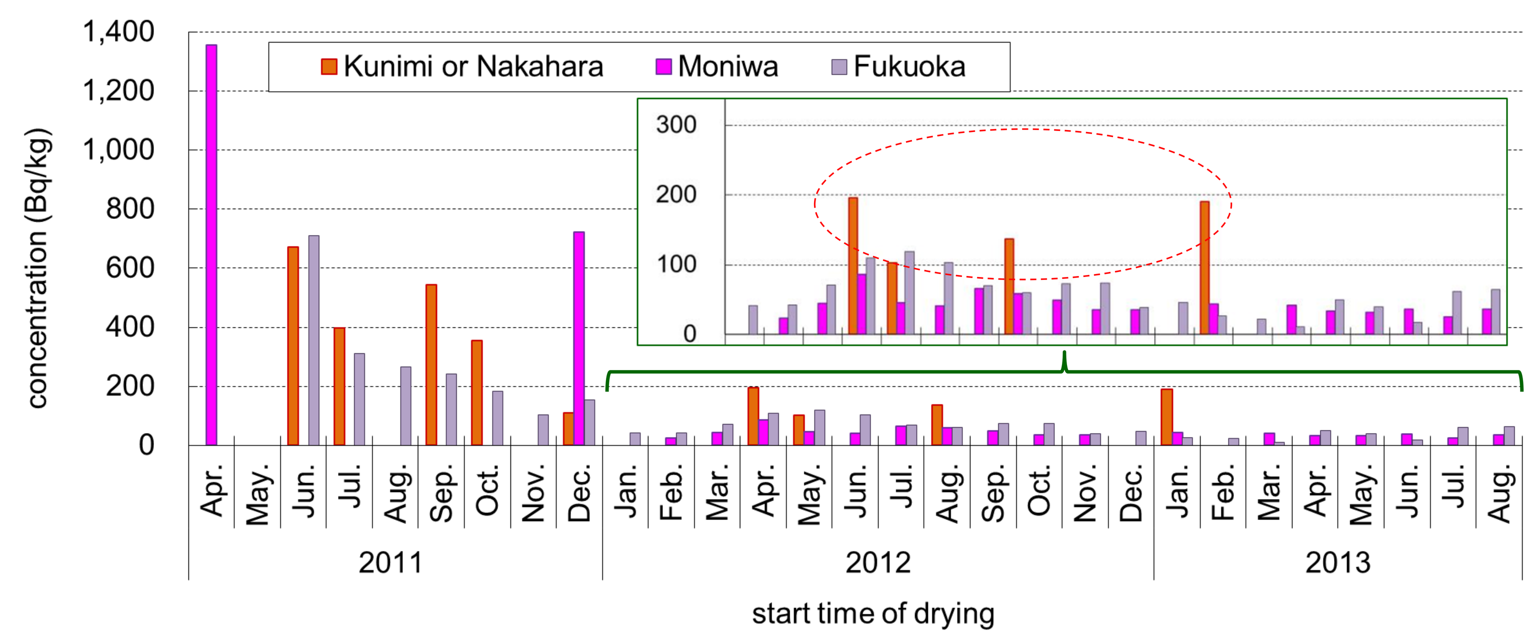

Figure 7 – Measurement result of ^{134}Cs and ^{137}Cs in dehydrated sludge cake (water content ratio:70%).

Fig. 7 shows the measurement result for ^{134}Cs and ^{137}Cs in dehydrated sludge cake at our WPPs by river system. We compared cakes that started drying from April 2011 to August 2013 with equal water content ratios (70%).
Different concentrations of radioactive cesium were detected even when the start time of drying was the same.
The cesium level in Moniwa was high and those in Kunimi & Nakahara showed a modest decline.

DISCUSSION

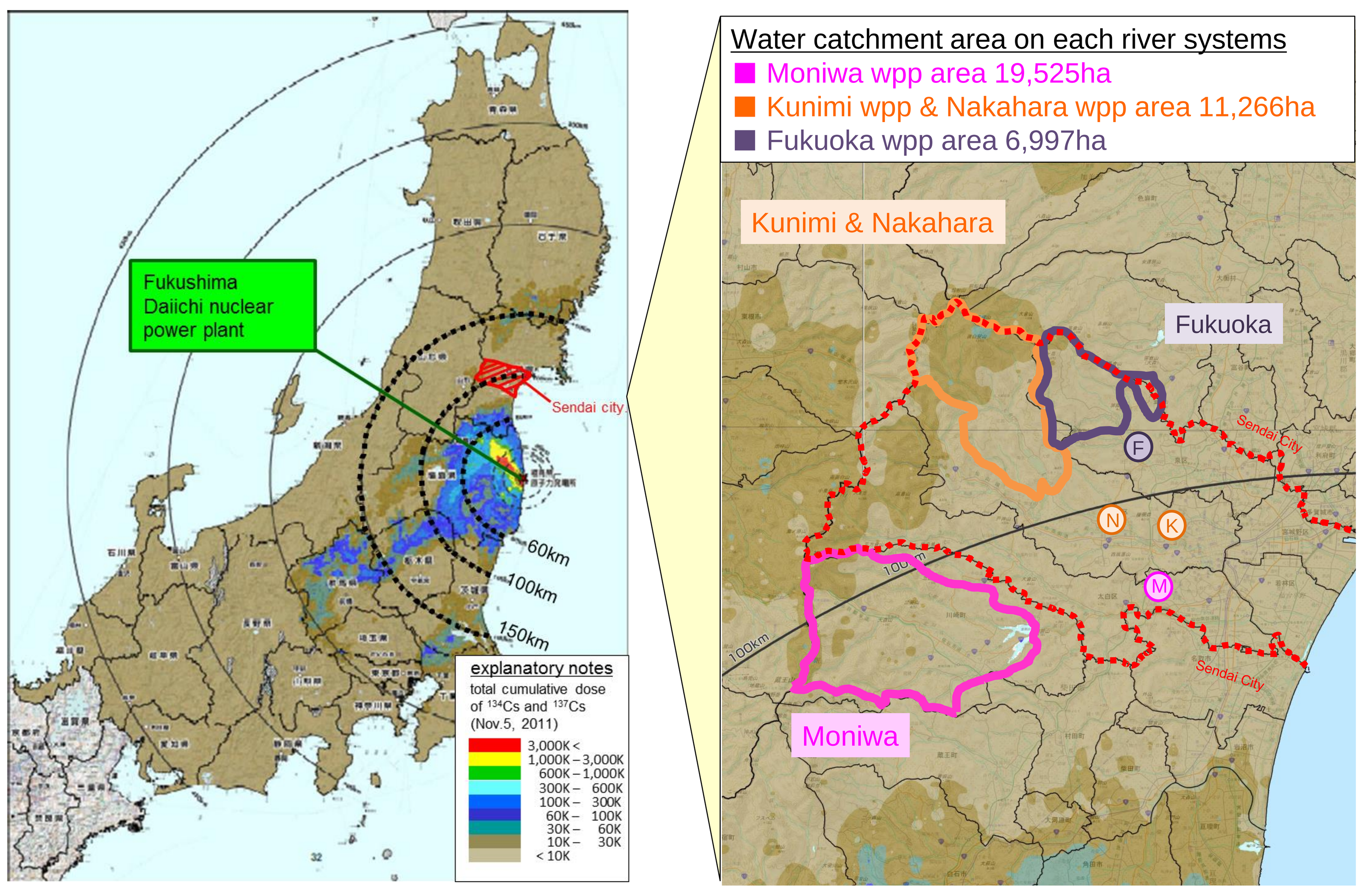

Figure 8 – Water catchment area and cumulative dose of ^{134}Cs and ^{137}Cs (Ministry of Education, Culture, Sports, Science and Technology, 2011[3])

The concentration of ^{134}Cs and ^{137}Cs in dehydrated sludge cake differs by river system. This might be caused by the difference in water catchment area or the cumulative dose of ^{134}Cs and ^{137}Cs.
No marked difference was found in land use and vegetation in forested areas among the river systems (data not shown).

CONCLUSIONS

- The maximum concentrations of radioactive iodine and cesium in treated water were 6.5Bq/kg and 1.4Bq/kg, respectively. These results were much lower than the hazard index levels (radioactive iodine: 300Bq/kg (100Bq/kg for infants), radioactive cesium: 200Bq/kg) set by the MHLW. It was suggested that radioactive cesium was removed in the process of water purification because ^{134}Cs and ^{137}Cs were detected in dehydrated sludge cake.
- The maximum concentration of ^{134}Cs and ^{137}Cs in dehydrated sludge cake was about 671~1,356Bq/kg in each river system. These differences may be attributed to a difference in the water catchment area or the cumulative dose of ^{134}Cs and ^{137}Cs.
- At present, the radioactive cesium level in dehydrated sludge cake is almost less than 100Bq/kg, so the reutilization rate of dehydrated sludge cake is expected to return to the pre-disaster level by March 2015.

References:
[1]Ministry of Health, Labour, and Welfare, 2011. Interim Report for Measures against Radioactive Materials in Drinking Water (in Japanese). Retrieved from http://www.mhlw.go.jp/topics/ bukyoku/kenkou/suido/houkoku/suidou/111101-1.html
[2]Ikemoto, T. and Magara, Y. 2011. Measures against impacts of nuclear disaster on drinking water supply systems in Japan. Water Practice & Technology 6, doi:10.2166/wpt.2011078.
[3]Ministry of Education, Culture, Sports, Science and Technology, 2011. Results of the Fourth Airborne Monitoring Survey (in Japanese). [Press Release] Retrieved from http://radioactivity.nsr.go.jp/ja/contents/5000/4901/24/1910_1216.pdf.