Analysis Results on Radioactive Substances Found in Naraha Town

< Reference >
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Tokyo Electric Power Company

- Substances contaminated with high-dose radiation were found during work including decontamination, which was conducted in Naraha Town, Hutaba County, Fukushima Prefecture (included in the areas to which evacuation orders are ready to be lifted) by Fukushima Office for Environmental Restoration under the Ministry of the Environment (MOE). Subsequently, MOE requested us to analyze those substances (4 substances in total) in July, 2013.

- Given the possibility that the substances are resultant from the accident at Fukushima Daiichi Nuclear Power Station, we brought them into Fukushima Daiichi NPS for analysis. As a result of the analysis, although how these substances were contaminated with such high-dose radiation remains unknown, we presumed that they are substances contaminated with radioactive materials, attributable to the accident at Fukushima Daiichi NPS, attached to them. (Previously announced on July 23, 2013)

- Then, we requested Japan Atomic Energy Agency (JAEA) to conduct detailed analysis (radioactivity quantitative analysis and component analyses). We received a report on the analysis results from the Agency recently, and complied the results.

Radioactive substances which MOE requested us to analyze

	Date when found	Location	Size (Dose rate)*	Appearance	Characteristics
Substance ①	June 20, 2013	Near the mouth of the Idegawa river in Naraha Town	Length: Approx. 3cm Width: Approx. 1.5cm Thickness: Approx. 0.5cm (γ : 85 μ Sv/h, β : 915 μ Sv/h)		- Non-metal - Elastic - Rubber-like Material
Substance ②	July 2, 2013	Near the mouth of the Idegawa river in Naraha Town	Length: Approx. 4cm Width: Approx. 3cm Thickness: Approx. 1cm (γ : 300 μ Sv/h, β : 2100 μ Sv/h)		- Non-metal - Elastic - Tree bark-like material
Substance ③	July 5, 2013	Near the mouth of the Idegawa river in Naraha Town	Length: Approx. 2cm Width: Approx. 2cm Thickness: Approx. 0.1cm (γ : 400 μ Sv/h・ β : 35600 μ Sv/h)		- Non-metal - Inelastic - Fragile material
Substance ④	July 5, 2013	Near the mouth of the Idegawa river in Naraha Town	Length: Approx. 16cm Width: Approx. 2cm Thickness: Approx. 0.5cm (γ : 180 μ Sv/h・ β : 600 μ Sv/h)		- Non-metal - Inelastic - Piece of wood

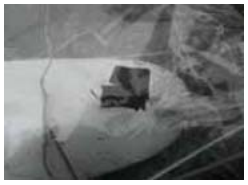
Analysis: TEPCO

* γ : 1-cm dose equivalent rate (γ ray), β : 70-μm dose equivalent rate (β ray)

Results of analysis for amounts of radioactivity (1)

< γ -ray nuclide analysis results >

Units: Bq/Sample

Material No.	Appearance	Amounts of radioactivity Values as of September 26, 2013						
		Mn-54	Co-60	Ru-106	Ag-110m	Sb-125	Cs-134	Cs-137
①		4.3×10^{0}	5.7×10^{1}	4.9×10^{1}	4.1×10^{1}	8.6×10^{2}	3.5×10^{5}	7.9×10^{5}
②		1.1×10^{1}	2.5×10^{2}	1.3×10^{2}	1.1×10^{2}	2.7×10^{3}	8.2×10^{5}	1.8×10^{6}
③		4.2×10^{1}	4.9×10^{2}	3.9×10^{2}	2.5×10^{2}	6.8×10^{3}	9.2×10^{5}	2.0×10^{6}
④		6.9×10^{1}	6.0×10^{2}	4.1×10^{2}	2.3×10^{2}	9.4×10^{3}	6.0×10^{5}	1.3×10^{6}

Weights of the samples: ①0.3g, ②1.0g, ③0.4g, ④6.9g

Analysis: JAEA

* Mn: manganese, Co: cobalt, Ru: ruthenium, Ag: silver, Sb: antimony, Cs: Cesium

Results of analysis for amounts of radioactivity (2)

< α and β nuclide analyses results >

Units: Bq/Sample

Material No.	Amounts of radioactivity (As of September 26, 2013 except for gross β, the values of which are as of October 17)						
	Gross β	Sr-90	Gross α	Pu-239＋Pu-240	Pu-238＋Am-241	Cm-242	Cm-244
①	1.2×10^{6}	2.3×10^{2}	5.2×10^{-1}	1.3×10^{-1}	2.7×10^{-1}	7.3×10^{-2}	4.8×10^{-2}
②	2.3×10^{6}	8.5×10^{2}	1.9×10^{0}	3.0×10^{-1}	1.1×10^{0}	2.7×10^{-1}	2.0×10^{-1}
③	2.5×10^{6}	2.2×10^{3}	3.8×10^{0}	6.7×10^{-1}	2.4×10^{0}	4.8×10^{-1}	3.0×10^{-1}
④	2.2×10^{6}	1.4×10^{3}	4.6×10^{0}	1.1×10^{0}	2.5×10^{0}	4.3×10^{-1}	5.7×10^{-1}

Analysis: JAEA

Weights of the samples: ①0.3g, ②1.0g, ③0.4g, ④6.9g

* Sr: strontium, Pu: plutonium, Am: americium, Cm: curium

Proportions of the amounts of radioactivity

In the total amounts of radioactivity, Cs-134 and Cs-137 account for proportions not less than 99%. The surface dose rates are substantially attributable to Cs-134 and Cs-137.

<Proportions of the amounts of radioactivity>

Units: %

Material No.	Mn-54	Co-60	Ru-106	Ag-110m	Sb-125	Cs-134	Cs-137	Sr-90	Pu-239＋Pu-240	Pu-238＋Am-241	Cm-242	Cm-244
①	<0.001	0.005	0.004	0.004	0.075	30.668	69.223	0.020	<0.001	<0.001	<0.001	<0.001
②	<0.001	0.010	0.005	0.004	0.103	31.249	68.596	0.032	<0.001	<0.001	<0.001	<0.001
③	0.001	0.017	0.013	0.009	0.232	31.397	68.255	0.075	<0.001	<0.001	<0.001	<0.001
④	0.004	0.031	0.021	0.012	0.492	31.379	67.988	0.073	<0.001	<0.001	<0.001	<0.001

Analysis: JAEA

Consideration on detection of radioactive materials

The detected densities of Cs-137, which accounted for the largest proportions of the radioactivity, have higher orders of magnitude than those in soil outside of the station site. Additionally, Co-60, which has not been detected in soil outside of the station site. For these reasons, they were presumed as substances from the power station.

Units: Bq/g

	Cs-137	Co-60
①	10^{6}	10^{2}
②	10^{6}	10^{2}
③	10^{6}	10^{3}
④	10^{5}	10^{1}
Debris around Unit 3 *1	10^{3} – 10^{5}	10^{-1} – 10^{0}
Soil outside of the station site (Naraha Town and Hirono Town) *2	10^{-1} – 10^{0}	- *3

*1: Radioactivity analysis on debris and cut-down trees from Fukushima Daiichi NPS (Japan Atomic Energy Agency: March 28, 2013)
*2: Results of a soil radiation monitoring survey in Fukushima Prefecture (Nuclear Emergency Response Headquarters and Fukushima Prefecture's Emergency Response Headquarters: April 6, 2012)
*3: Co-60 was not detected, and this cell therefore shows “-”.

Results of cross-sectional observation and component analysis (FT-IR)

Substance No.	Cross-sectional observation	Results of cross-sectional observation	Results of FT-IR analysis
①		White inside, and having small holes. Having a dirt-like substance attached to the surface.	Presumed to be polyethylene. Having a silica component attached to the surface.
②		White inside, and having small holes. Having a dirt-like substance attached to the surface.	Presumed to be polyethylene. Having a silica component attached to the surface.
③		White inside. Black outside.	Presumed to be of a polyolefin high-polymer material. Having a silica component and hydroxyl (moisture) attached to the surface.
④		Having a woody cross section.	A piece of wood (cellulose). No difference between the surface and the interior.

Analysis: TEPCO

FT-IR Analysis: Fourier transform infrared spectroscopy analysis (a method by which the kind of a compound is presumed based on measurement of the infrared-absorbing spectrum of the compound molecules).

Results of component analysis (EPMA)

[Substance ①] Cross section / Surface

Element	No.1	No.2	No.3	No.4
C	91.2	91.5	12.6	28.5
N				
O	8.8	7.9	11.3	29.5
Na				
Mg				0.3
Al			0.6	4.0
Si		0.7	28.0	32.1
P			3.3	0.4
S			2.1	1.3
Cl			1.3	
K			4.0	0.6
Ca			18.4	1.0
Ti			2.4	1.5
Mn			1.8	
Fe			14.2	0.8
Br				
I				
Total	100.0	100.0	100.0	100.0

[Substance ②] Cross section / Surface

Units: %

Element	No.1	No.2	No.3	No.4
C	72.1	100.0	16.7	28.7
N			5.2	6.6
O	11.8		38.7	37.4
Na			0.2	0.5
Mg	0.5		3.1	0.8
Al	2.5		10.1	6.4
Si	10.0		17.2	14.6
P			0.3	0.2
S				0.2
Cl	0.3			
K	0.2		0.3	0.5
Ca	0.4		1.0	0.8
Ti	0.6		0.4	0.9
Mn			0.3	
Fe	1.6		6.5	2.4
Br				
I				
Total	100.0	100.0	100.0	100.0

Analysis: JAEA

- For each of Substances ① and ②, measurement was performed at locations along the cross section（No.1 and No.2）and locations on the surface (No.3 and No.4).
- Each of the relative concentrations of C includes a contribution of C deposited for securing conductivity of the sample.

* EPMA analysis: Electron microprobe analyzer (a method by which constituent elements are analyzed based on the wavelength and strength of a characteristic X ray that occurs when an electron is irradiated to an analysis object.)

Results of component analysis (EPMA)

[Substance ③] Cross section / Surface

Element	No.1	No.2	No.3	No.4
C	90.1	43.9	24.5	55.8
N		8.0	5.6	
O	5.2	16.9	31.5	13.3
Na		0.3	1.0	0.5
Mg		1.3		0.7
Al		3.8	7.8	2.7
Si		9.6	26.2	4.9
P				0.9
S		0.4		0.8
Cl	0.7	0.2		1.2
K		0.4	2.7	0.4
Ca	2.4	9.8	0.4	6.7
Ti	1.6	0.8	0.3	10.4
Mn				
Fe		4.6		1.7
Br				
I				
Total	100.0	100.0	100.0	100.0

[Substance ④] Cross section / Surface — Units: %

Element	No.1	No.2	No.3	No.4	No.5	No.6
C	82.1	86.2	74.9	82.2	77.5	68.7
N						
O	6.8	6.6	11.6	8.8	9.6	8.3
Na	0.5	0.5				
Mg	1.4	1.0	0.6	0.9	1.5	0.9
Al	0.4	0.3	1.4	0.5	0.7	2.2
Si	0.7	0.2	7.1	0.8	1.4	3.0
P	1.3	1.1	0.4	0.6	1.1	
S	0.3	0.6		0.9	0.9	2.9
Cl	0.3	0.4	0.4	0.7	0.5	0.9
K	0.4	0.6	0.6	0.4	0.6	0.8
Ca	5.1	2.6	1.4	3.1	5.2	2.9
Ti			0.2			0.6
Mn						
Fe	0.7		1.2	1.1	1.0	2.0
Br						5.2
I						1.6
Total	100.0	100.0	100.0	100.0	100.0	100.0

Analysis: JAEA

- For Substance ③, measurement was performed on locations along the cross section（No.1 and No.2）and locations on the surface (No.3 and No.4). For Substance ④, measurement was performed on locations along the cross section（No.1 to No. 3）and locations on the surface (No.4 to No.6).
- Each of the relative concentrations of C includes a contribution of C deposited for securing conductivity of the sample.

Analysis for seawater components using mock samples (pieces of wood)

As a result of the component analysis, it was noted that small amounts of Na and Cl, which are seawater components, were found attached to each of the samples. Therefore, in order to conduct studies for the routes that the samples had taken from the power station site (whether the routes were by sea or land), analysis was conducted on Na and Cl components attached to mock samples (pieces of wood) as a result of exposing the mock samples to seawater and salt air.

	No exposure	[Study 1] Sample soaked in artificial seawater	[Study 2] Sample soaked in pure water	[Study 3] Sample exposed to salt air at a beach
Piece of wood found on the water's edge of another beach	①	–	②	–
New piece of wood	③	④	⑤ *	⑥

* In an additional study 1, a sample soaked in artificial seawater was soaked in pure water.

[Study 1] Study on attachment of Na and Cl to a sample soaked in artificial seawater

This study was conducted to see how much Na and CL are attached to a sample after it has been soaked in seawater.

[Study 2] Study on attachment of Na and Cl to a sample soaked in pure water

This study was conducted to see whether the amounts of Na and Cl attached to a sample decrease or not when rainwater or plain water washes them.

[Study 3] Study on attachment of Na and Cl to a sample exposed to salt air at a beach

This study was conducted to see how much Na and CL are attached to a sample after it has been exposed to salt air at a beach.

Results of component analysis (EPMA)

[Piece of wood found on the water's edge of another beach] **[New piece of wood]** Units: %

	① Samples left as it was when found		② Samples soaked in pure water after it was found		③ Samples kept in a new state		④ Samples soaked in artificial seawater		⑤ Samples obtained by soaking the samples of ④ in pure water		⑥ Samples obtained by exposing a new piece of wood to salt air at a beach	
Element	①−1	①−2	②−1	②−2	③−1	③−2	④−1	④−2	⑤−1	⑤−2	⑥−1	⑥−2
C	64.7	64.3	57.0	65.8	56.3	60.2	51.5	44.5	52.7	53.1	68.9	56.7
N								15.0			1.1	3.1
O	34.2	34.6	42.7	32.7	43.2	38.0	46.2	39.9	45.7	46.2	29.6	39.9
Na	0.4	0.3			0.1	0.1	0.6	0.2	0.5	0.3	0.1	0.1
Mg			0.1									0.1
Al												
Si												0.1
P		0.1		0.2			0.2	0.1				
S	0.1	0.4			0.1			0.1			0.1	
Cl		0.1				0.4	0.7	0.2	0.5	0.2		
K		0.2		0.1	0.1	0.1			0.1	0.1		
Ca	0.4			0.1	0.1		0.6		0.1			
Ti	0.1		0.2									
Mn								0.1				
Fe		0.1										
Br			0.1	0.1								0.1
I				0.9		1.0	0.1		0.3			
Total	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0

Analysis: JAEA

- For each of the samples, two locations along a cross section were measured. Each of the proportions of C includes a contribution of C deposited for securing conductivity of the sample.

We originally assumed that the samples of ① (taken from another beach) and the samples of ④ (soaked in seawater) would have the largest amounts of the seawater components attached on them. However, all of the samples showed Na concentrations and Cl concentrations not more than 1% (almost the same level as Substance ④ found in Naraha Town showed), and no qualitative difference was found among the mock samples.

Summary of the analysis results

- The results of surface dose rate measurement indicated high contributions of β rays. Since the amounts of radioactivity were mostly accounted for by Cs-134 and Cs-137, it is presumed that the **β rays are attributable to Cs-134 and Cs-137**。
- The detected densities of Cs-137, which accounted for the largest proportions of the radioactivity, have higher orders of magnitude than those in soil outside of the station site. Additionally, Co-60, which has not been detected in soil outside of the station site. For these reasons, the substances in question are presumed to **those that came from the power station**.
- Based on the results of the FT-IR analysis, it is presumed that Substances ① and ② are of polyethylene materials, that Substance ③ is of a polyolefin high-polymer material, and that Substance ④ is wood.
- As a result of the seawater component analysis, all of the samples showed Na concentrations and Cl concentrations not more than 1%. No quantitative difference was found between samples soaked in seawater and samples exposed to salt air at a beach.
- Either a sea route (reached the month of the river after having been soaked in seawater) or a land route (reached the month of the river without having been soaked in seawater) is thought possible as the route taken by each of the radioactive substances found near the month of the Ideigawa river. However, it was impossible to determine the route.