Current state of the marine environment in the Pacific Ocean

1. Radioactivity in seawater and marine soil by Japanese monitoring in 2012
2. Simulation of marine dispersion in the Pacific Ocean

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1. Radioactivity in seawater and marine soil by Japanese monitoring in 2012
Sea Area Monitoring Plan in FY2012

Basic concept of the revision of the monitoring plan is to ascertain
(1) concentration levels mainly for cesium-134,137 in seawater by enhancing
the analysis accuracy,
(2) the spatial distribution and chronological movement of radioactive
materials in marine soil and characteristics of marine soil,
(3) the chronological changes in radioactivity concentrations in fishery products with regard to marine organisms.

Furthermore, the monitoring content will be enhanced and strengthened by taking into account not only the routes of radioactive materials discharged into the sea from TEPCO’s Fukushima Dai-ichi NPP but also those of radioactive materials flowing into the sea from the land area via rivers.

When conducting the sea area monitoring, attention will also be paid to the viewpoints of helping the understanding of the movement of radioactive materials from the environment to marine organisms and the bioconcentration process.

Five sea areas

(i) Sea area close to TEPCO’s Fukushima Dai-ichi NPP: The area near the 1F-NPP requiring close watch

(ii) Coastal area: The area within about 30 km from the coastline of Aomori (only partially), Iwate to Miyagi, Fukushima and Ibaraki prefectures (including river outlets)

(iii) Off-shore area: The area within about 30 to 90 km from the coastline

(iv) Outer sea area: The area within about 90 to 280 km and 280 km or farther from the coastline

(v) Tokyo Bay: The closed sea area where radioactive materials are highly likely to flow in from rivers and be deposited in particular

Seawater

• In area(i), high frequency (dairy) monitoring with the aim of checking any new leakage of radioactive materials from the NPP with detection limit (DL) at 1 Bq/L. **TEPCO** will be in charge of this monitoring.

• In areas (ii)-(v), monitoring by lowering detection limits according to sea areas for the purpose of scientifically ascertaining long-term effects with DL at 1 mBq/L. **Mainly MEXT** will be in charge of this monitoring.

• Main objective nuclides are Cs-134,137, but sometimes H-3, Sr-89,90, I-131, Pu-238,239,240 etc. will be analyzed.

Marine soil

- Measuring points will be determined by taking into consideration river outlets and fishing grounds in order to understand the flow and movement of radioactive materials into the sea via rivers.
- In area(i) and part of (ii), monthly measurement for I-131 and Cs-134,137 are conducted with DL at 10 Bq/kg.
- The other areas except (iv), lower frequency measurement are conducted with DL at 1 Bq/kg.

Seawater in area (i)*

### Northern Side of the Water Discharge Canal of 5 and 6

- **Max:** 68,000 Bq/L (2011.4.7)

### Iwasawa coast (15km south of 1F-NPP)

- **Max:** 1,400 Bq/L (2011.4.5)

**BG level for $^{137}$Cs before the accident=0.001~0.002 Bq/L**

Seawater in area (ii)

<table>
<thead>
<tr>
<th>Year</th>
<th>Cs-134</th>
<th>Cs-137</th>
</tr>
</thead>
<tbody>
<tr>
<td>2012</td>
<td>ND~0.022</td>
<td>0.0017~0.032</td>
</tr>
<tr>
<td>Miyagi (27, June)</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Fukushima (27, July)</td>
<td>0.0034~0.069</td>
<td>0.0057~0.098</td>
</tr>
<tr>
<td>Ibaraki (6-9, August)</td>
<td>ND(&lt;1.1)</td>
<td>ND(&lt;1.1)</td>
</tr>
</tbody>
</table>

In Fukushima prefecture,
North < South
But less than 0.1 Bq/L

http://radioactivity.mext.go.jp/ja/contents/7000/6107/24/229_m_0831.pdf
Seawater in area (iii) (Bq/L)

<table>
<thead>
<tr>
<th>Date</th>
<th>Cs-134</th>
<th>Cs-137</th>
</tr>
</thead>
<tbody>
<tr>
<td>15-28, May, 2012</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Miyagi</td>
<td>~0.018</td>
<td>~0.029</td>
</tr>
<tr>
<td>Fukushima</td>
<td>~0.041</td>
<td>~0.060</td>
</tr>
<tr>
<td>Ibaraki</td>
<td>~0.055</td>
<td>~0.087</td>
</tr>
</tbody>
</table>

In 3 prefectures, North < South
Less than 0.1 Bq/L (Bq/L)

15-28, May, 2012

<table>
<thead>
<tr>
<th>Prefecture</th>
<th>Cs-134</th>
<th>Cs-137</th>
</tr>
</thead>
<tbody>
<tr>
<td>Miyagi(474m)</td>
<td>0.000068</td>
<td>0.00076</td>
</tr>
<tr>
<td>Fukushima (516m, 647m)</td>
<td>ND</td>
<td>0.00064</td>
</tr>
<tr>
<td>Ibaraki(558m)</td>
<td>0.00011</td>
<td>0.00088</td>
</tr>
</tbody>
</table>

Cs-137=BG level
Cs-134=1/10 of Cs-137

Trend of seawater in area (iii)

Concentration of Cs-137 had been decreasing till last September. But since then, unchanged in Miyagi and Fukushima, Fluctuated in Ibaraki, depending on desorption from marine soil? Inflow from river? Release from NPP?
Seawater in area (iv)

- 90-280km

Oyashio region
Maximum: 100m depth

Kuroshio region
Maximum: unclear

\[ { }^{134, 137} \text{Cs} \]

Nov.2011 – May.2012

Nov.2011

May.2012

May.2012

May.2012


Seawater in area (iv)

- 280km~

In May 2012: Less than 0.01 Bq/L

Surface seawater
Oct 2011: 0.025 Bq/L
June 2012: 0.001 Bq/L

Vertical profiles of $^{134}$Cs
at 40N, 165E on 12 Oct. 2011 Stn KS1109-3101
and
at 39N, 165E on 11 June 2012 stn RF1205-4418
$^{134}$Cs / Bq m$^{-3}$

Oxygen maximum

http://radioactivity.mext.go.jp/ja/contents/6000/5889/24/229_g_0802.pdf
$^{134}\text{Cs}$ in surface water in Jan. – Mar. 2012

Data sources: MEXT monitoring, Aoyama this study

Solid circle with color: observed data  unit: Bq m$^{-3}$

$0.01 \text{Bq/L} = 10 \text{ Bq m}^{-3}$

Aoyama, unpublished
Eastward movement of observed Fukushima origin $^{134}$Cs in surface water during the period from March 2011 to July 2012

Estimated speed: 8 cm s$^{-1}$

1800 km (140E->160E) 270 days

This is consistent with 4-16 cm s$^{-1}$

Aoyama, unpublished
Seawater samples collected during June 2012 by MRI are analyzing now. Only data from two stations at 39 deg.N and 35 deg. N along 165 deg. E are available.

## Marine soil in area (i)(ii)

### Northern Side of the Water Discharge Canal of 5 and 6

**Graph: (Bq/kg)**

<table>
<thead>
<tr>
<th>Year</th>
<th>2011</th>
<th>2012</th>
</tr>
</thead>
<tbody>
<tr>
<td>BG</td>
<td>0.8~1.4</td>
<td>0.8~1.4</td>
</tr>
<tr>
<td>1</td>
<td>1E6</td>
<td>1E6</td>
</tr>
<tr>
<td>2</td>
<td>1E5</td>
<td>1E5</td>
</tr>
<tr>
<td>3</td>
<td>1E4</td>
<td>1E4</td>
</tr>
<tr>
<td>4</td>
<td>100</td>
<td>100</td>
</tr>
<tr>
<td>5</td>
<td>10</td>
<td>10</td>
</tr>
</tbody>
</table>

### Data for July, 2012

<table>
<thead>
<tr>
<th>Distance</th>
<th>Cs-134</th>
<th>Cs-137</th>
</tr>
</thead>
<tbody>
<tr>
<td>~20km</td>
<td>11~1800</td>
<td>21~2700</td>
</tr>
<tr>
<td>20~30km</td>
<td>7.1~140</td>
<td>9.9~230</td>
</tr>
<tr>
<td>30km~</td>
<td>17~230</td>
<td>23~330</td>
</tr>
</tbody>
</table>

### Chart:

- Northern side of the discharge canal of reactor 5 and 6
- Data points indicate concentration levels of Cs-134 and Cs-137 in marine soil
- Colors represent concentration ranges:
  - Purple: >1000 Bq/kg
  - Red: 100~1000 Bq/kg
  - Orange: 10~100 Bq/kg
  - Green: <10 Bq/kg

### Additional Information:

The concentration in marine soil varied widely, if taken at the same places.

<table>
<thead>
<tr>
<th></th>
<th>Cs-134</th>
<th>Cs-137</th>
</tr>
</thead>
<tbody>
<tr>
<td>Miyagi</td>
<td>~15</td>
<td>~23</td>
</tr>
<tr>
<td>Fukushima</td>
<td>~110</td>
<td>~160</td>
</tr>
<tr>
<td>Ibaraki</td>
<td>~190</td>
<td>~280</td>
</tr>
</tbody>
</table>

Marine soil in area (iii)
## Current state of Cs-137 in seawater and marine soil in 2012

<table>
<thead>
<tr>
<th>Area</th>
<th>Seawater (Bq/L)</th>
<th>Marine soil (Bq/kg)</th>
</tr>
</thead>
<tbody>
<tr>
<td>(i) Close to NPP (discharge ports)</td>
<td>1 -10</td>
<td>20-3000</td>
</tr>
<tr>
<td></td>
<td>0.1-1</td>
<td></td>
</tr>
<tr>
<td></td>
<td>(Iwasawa coast)</td>
<td></td>
</tr>
<tr>
<td>(ii) Coastal area</td>
<td>0.002-0.1</td>
<td>10-400</td>
</tr>
<tr>
<td>(iii) Off-shore area</td>
<td>BG-0.1</td>
<td>10-300</td>
</tr>
<tr>
<td>(iv) Outer sea area</td>
<td>BG-0.01</td>
<td>No data</td>
</tr>
<tr>
<td>BG before accident*</td>
<td>0.0011-0.0018</td>
<td>0.8-1.4</td>
</tr>
<tr>
<td></td>
<td>Offshore 1F NPP in 2010</td>
<td></td>
</tr>
</tbody>
</table>

Sr-90 in seawater and marine soil

Near 1F NPP

- Seawater: ND~0.15 (Bq/L), 100 times of BG(0.001), 0.1 time of $^{137}$Cs
- Marine soil: ND~3.4 (Bq/kg), 100 times of BG(0.03), 0.001 time of $^{137}$Cs
- The ratio of $^{90}$Sr/$^{137}$Cs was increasing, because of leakage of processed (Cs-removed) reactor water?

(Povinec at al., 2012)
2. Simulation of marine dispersion in the Pacific Ocean
Re-simulation by LAMER

EU meeting in 2011

(Nakano and Povinec, 2012)

15 * 0.5 + (0.94 + 0.0096) = 8.45 PBq

8.45 PBq (direct)

2 PBq (outside of map)

6 PBq (deposition to ground)

4 PBq (direct)

5 PBq (deposition to sea)

Deposition Cs-137 (Bq/m²)

Kawamura et al. (2011)

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Re-simulation by LAMER

(Nakano and Povinec, 2012)

- Almost same movement with the previous calculation with the preliminary source term.
- Maximum concentration of Cs-137 in April 2012 was calculated as 21 Bq/m³ (=0.021 Bq/L) at 38N, 164E. (23 Bq/m³ by the previous calculation)
Comparison with the observed concentration in seawater

Comparison of Cs-137 concentration in seawater outside 200 nautical mile line (= 370km) due to Fukushima accident (BG(0.001) was reduced.)

Nakano, unpublished
Simulated Cs-137 concentration in fish outside 200 nautical mile line

Simulated max concentration in fish at equilibrium at time(t) = $C_w(t) \times CF(fish)$

$C_w(t)$: simulated maximum concentration in seawater
$CF(fish)$: concentration factor of fish ($=100$)

If you take 64-g fish of this concentration (2 Bq/kg) everyday, you will receive $0.62\mu$Sv/a from $^{137}$Cs and $0.80\mu$Sv/a from $^{134}$Cs.

The observed data was extracted from the website of “http://www.jfa.maff.go.jp/e/inspection/index.html”

Nakano, unpublished
Dose assessment in 2012-2014

- Internal exposure by the intake of the marine products in 2012 would be 1.67 micro Sv per year mainly from $^{134+137}$Cs in fish, when adopting the maximum concentration and the averaged Japanese diet.
- Internal exposure in 2013 and 2014 would be 0.74 and 0.41 micro Sv per year, respectively.
- Because the dose is proportional to the consumption amount of sea food, most public in the world will get lower doses than the Japanese population.

<table>
<thead>
<tr>
<th>Species</th>
<th>Internal dose in 2012 ($\mu$Sv/a)</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>$^{90}$Sr</td>
</tr>
<tr>
<td>Fish</td>
<td>0.0040</td>
</tr>
<tr>
<td>Crustaceans</td>
<td>0.00057</td>
</tr>
<tr>
<td>Cephalopods</td>
<td>0.00023</td>
</tr>
<tr>
<td>Shellfish</td>
<td>0.00074</td>
</tr>
<tr>
<td>Seaweed</td>
<td>0.0021</td>
</tr>
<tr>
<td>Total</td>
<td>0.0077</td>
</tr>
</tbody>
</table>
$^{134}$Cs in surface water  

By Aoyama (unpublished)

Data sources: NYK ships, Inoue et al., MEXT, Hakuho

Solid circle with color: observed data

Pattern: Atmospheric model with ocean model simulation

Source term Chino et al. 8.8 PBq for atmospheric release and Tsumune et al., 3.5 PBq for direct discharge

unit: Bq m$^{-3}$
Conclusion

• The concentration of $^{134,137}$Cs in seawater near 1F-NPP was considerably decreased to 1~10 Bq/L in 2012, which is 1,000-10,000 times of BG level.

• The concentration of $^{134,137}$Cs in the deep Pacific is BG~0.01 Bq/L, which is 10 times of BG level.

• The simulation by LAMER estimated the concentrations of $^{137}$Cs in seawater and marine products. The result agrees the observation of them.

• The internal dose from Japanese consumption of all marine product was estimated to be 1.7, 0.74 and 0.41 micro Sv/a in 2012, 2013 and 2014, respectively.