Contamination of water, sediments and biota of the Northern Pacific coastal area in the vicinity of the Fukushima NPP

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Abstract:
Caused by the nuclear accident at Fukushima Daiichi NPP, considerable amount of radionuclides in particular those of J-131, Cs-134 and Cs-137 was released into the sea environment. As for Sr-90, it was measured only sporadically and in negligible activity concentrations in water and sediments whereas there no Pu isotopes were detected in the sea.

Maximum concentrations of J-131 and Cs-137 in the seawater were measured on 30-03-2011 at 180,000 Bq/l and 47,000 Bq/l in offshore waters at the NPP site. Later the concentration values of both nuclides abated exponentially while indicating some fluctuations and since early April 2011 making less than 100 Bq/l and since 10 May remaining constantly lower than the quoted detection limit of about 6 Bq/l. In March up to 100 Bq/l for J-131 and Cs-134 and Cs-137 were measured at the distance of 20 through 60 km from the coastline, that both in the surface water and also in deep water. Whereas the short-lived I-131 was no more detectable ever since mid-April for that distance, all measurement values for Cs-134 and Cs-137 have been lower than the detection limit since the second May decade. Activity concentration values for Cs-134 and Cs-137 in bottom sediments amounted to at most 750 Bq/kg and 910 Bq/kg in the vicinity of the NPP, and that between 1 Bq/kg and 100 Bq/kg at the distance of 30 or more kilometers.

Activity values of radioactive cesium (Cs-134 and Cs-137) in fish in the vicinity of the NPP sometimes amounted to more than 1,000 Bq/kg, however measuring less than 10 Bq/kg radioactive cesium in the fishing grounds of Northern Pacific at the distance of some 100 km. In other seafood species from the coastal areas only sporadical total cesium contents of higher than 500 Bq/kg were measured.

As the seaside setting of the Fukushima NPP is restricted up to about 30 km for fishing of seafood and seaweed, and while current Cs concentration values in water, sediments and fish measured at greater distance remaining inconspicuous, there is no danger for people to be posed by consumption of fish and seafood from those particular Pacific fishing grounds.

1 INTRODUCTION

Immediately after the occurrence of the nuclear accident at Fukushima Daiichi NPP the GRS established an emergency centre for the evaluation of the nuclear safety of the NPP and the local and regional radiological situation in Japan and on possible consequences for Europe. The evaluated data and information were delivered to the BMU, mass media and the public. For this, the results of radioactivity measurement in the marine environment carried out by the plant owner TEPCO and by Japanese Authorities were registered. These information and data were evaluated by means of ecological models and statistical methods and spread via GRS website to the public. The first report on preliminary evaluation of the contamination of the marine environment in the vicinity of the Fukushima NPP was published mid-April followed by some updates. The report on hand is basing upon measurements of TEPCO, MEXT and MAFF until mid-October 2011.
2 CRONOLOGICAL SEQUENCE OF RADIOACTIVE CONTAMINATION IN THE SEA ENVIRONMENT

2.1 Seawater

The results of investigations on the chronological development of the seawater contamination in the immediate vicinity of NPP Fukushima are demonstrated in Fig. 1 for Cs-137 and in Fig. 2 for I-131 basing upon measurements of TEPCO /1/. Following strong fluctuations in activity concentrations, on 30-03-2011 the maximum of at 180.000 Bq/l for I-131 was detected at the measurement point at a distance of 330 m south of the outlet pipe. Simultaneously, the respective maximum of 47.000 Bq/l occurred for Cs-134 and Cs-137. Afterwards, the concentration of both nuclides abated exponentially and with some fluctuations, while being lower than the authorized limits of seawater contamination of 40 Bq/l for I-131, 60 Bq/l for Cs-134 and 90 Bq/l for Cs-137 since late April 2011. It is approximately since 10 Mai that the activity concentration for I-131 has been lower than the detection limit of about 6 Bq/l, whereas the values for Cs-134 and Cs-137 being constantly below the detection limit since mid-July.

![Seawater contamination with Cesium-137](image)

**Fig. 1:** Seawater contamination with Cesium 137 in the vicinity of Fukushima NPP (data source: TEPCO /1/)
Fig. 2: Seawater contamination with Iodine 131 in the vicinity of Fukushima NPP (data source: TEPCO /1/)

The scrutiny of the seawater contamination at a greater distance from NPP Fukushima has been carried out by the Ministry of Technology (MEXT) /2/ since 23-03-2011 at a total of 28 measuring points at distances of 35 through 60 km from the NPP site. The I-131 maximum was detected on 15-04-11 at three measuring points directly east of the NPP at a distance of 35 through 40 km with the activity concentration of 34 through 160 Bq/l. The highest Cs-137 activity was also measured on 15-04-11 amounting to 165 Bq/l at one of these three measuring points. The latest detectible activities for Cs-134 and Cs-137 in the surface water were measured on 11-5-2011 amounting to 9 Bq/l and 11 Bq/l (about 40 km northeast). Measurement data from MEXT for the nearground water have been available since 28-03-11. There, concentrations of up to 12.6 Bq/l for Cs-137 and 6.0 Bq/l for I-131 were measured. Owing to the dilution and radioactive decay, concentrations of I-131 have been lower than the detection limit since mid-April. Cs-134 and Cs-137 in deepwater were indicated for the last time in early May.

2.2 Bottom sediments

The predominantly sandy ground sediments in the sea areas off Fukushima indicated 160 Bq/kg at most for Cs-134 and 210 Bq/kg for Cs-137 at the measuring point of 30 km eastward (water depth of 126m) on 24-05-11. At this measuring point also the highest cesium activity in water was detected. Whereas the concentration of I-131, due to the short half-life of 8 days, was lower than the detection limit already in mid-May, activity of Cs-134 and Cs-137 at the same measuring point still amounted to 140 Bq/kg and 170 Bq/kg on 21-06-11 and 91 Bq/kg and 110 Bq/kg on 06-07-11. Also at other measuring points, only a slight decrease of Cs activity was detected, whereas at some measuring points the cesium activity for bottom sediments in summer 2011 even increased. Further increase of the cesium activity in bottom sediments is not to be expected owing to a strong decrease in water contamination. Also it can be indicated that the abovementioned sediment contamination is very low as compared to the onshore measurement values. To this end, even at a distance of some 30 km, concentration of Cs 137 up to about 40,000 Bq/kg
(Sukagawa), and in one case that even up to 140,000 Bq/kg (Itate, 5-5-2011) were measured.
The seaground off Fukushima consists of mainly sand which hardly accumulates cesium, while binding only fine particles. By destruents living in the seaground and in the pore water, cesium is rushly mineralized. Whereas the decrease of cesium contamination onshore depends mostly on the physical half-life amounting 30 years for Cs 137 thus constituting a very slow process, the effective half-life is decisive for the decrease in activity in the sandy bottom sediments off Fukushima accelerated by processes like mineralization, diffusion and convection so that even for Cs 137, a significantly speedy decrease of activity in sediments should be expected than it would be the case when only the physical half-time is considered.

2.1 Marine organisms

The enrichment of radionuclides in marine organisms reflects its specific metabolic characteristics as related to the chronology of the seawater contamination as follows.

2.1.1 Seaweed

Seaweed (like green algae, red algae and brown algae) are in highly appreciated as food in Japan. They all accumulate Iodine with an enrichment factor from 100 (Nori, red algae) up to 10,000 (Kombu, brown algae). As intake of I-131 would also mean stable Iodine, it theoretically results in concentration of I-131 which amounts at most to the 10,000-fold of I-131 concentration in seawater. Also, the decrease in I-131 concentration, with a short time delay, follows the contamination trend for I-131 in the seawater, for I-131 in the algae is being exchanged by the stable Iodine. This is also true for cesium, whereas it is generally contained as ions in cell water of algae.

2.1.2 Shellfish, shrimps, mussels, snails, and calamary

Even if numerous radioactivity measurements of mussels, crabs, snails and shrimps from the coastal area off Fukushima demonstrate higher activity values for Cs-134 and Cs-137, they are nevertheless, - irrespective of some few cases with 650 Bq/kg and 820 Bq/kg in Mediterranean mussel on 16-05-11; with 940 Bq/kg in surf clam on 28-05-11 and 610 Bq/kg on 06-06-11 and with 1,930 Bq/kg in Japanese mitten crab on 19-06-11 - always lower than that of the maximum of 500 Bq/kg in seefood allowed by the Japanese government for cesium (total). For these seafood, I-131 was detectable until late May, e. g. in Ezo abalone (edible sea snail) with 80 Bq/kg, while radioactive cesium amounted to 290 Bq/kg. Activity values in crustacean and calamary from remote sea areas were respectively lower by about 20 Bq/kg in shrimp and up to 40 Bq/kg in calamary (but for a case with 360 Bq/kg cesium on 09-05-11).

2.1.3 Fish

The evaluation of the radioactivity measurements in marine fish was separately carried out for sandlances, flatfish and pelagic fish due to there different living habitats.

2.1.3.1 Sandlance

Sandlance often occurs in the coastal waters off Fukushima. It is, on the one hand, a demanded edible fish in Japan and, on the other hand, it constitutes fodder for cod, pollock and seabirds. Due to its way of life and eating habits (mostly small crustaceans) it strongly accumulates the radionuclides from the sea. Thus, up to 14,400 Bq/kg radioactive cesium (total) and 12,000 Bq/kg I-131 were measured in sandlance from the coastal area off
Fukushima in mid-April. Whereas I-131 has not been detected since the last May decade in the sandlance from area off Fukushima, thereof for Cs activity was still measured amounting up to 400 Bq/kg in late September 2011.

### 2.1.3.2 Flatfish

The flatfish living on the seaground, in particular flounder, accumulate like the sandlance and due to their way of life and eating habits, (small crustaceans, plants residues, detritus) also the radionuclides from the sea, in particular, that of cesium. Therefore, the respective cesium concentration rose with a major delay in time as compared to that of the water contamination and in late May amounted to some activity concentration of 250 Bq/kg Cs total, remaining at this level by now (early October). The maximum cesium activity concentration in flounder was detected at 1,610 Bq/kg on 10-09-11. For sole and halibut, the trend is similar though with lower activity concentrations. Cesium activity concentration for the flatfish from the coastal areas off Fukushima should decrease accordingly to the sediments contamination and would decrease yet at the end of the year. As for I-131, it was detected only from early April until mid-April with lower activity values (mostly <10 Bq/kg, max. 35 Bq/kg on 31-03-11).

### 2.1.3.3 Pelagic fish

Of those fished from the high sea at larger distance off NPP Fukushima and investigated for radioactivity, the most important edible fish are cod, pollock, seabass, mackerel, herring, anchovy, sardine, dory, and tuna. The results of cesium activity measurements of those fish species demonstrate a step-by-step increase of contamination until June. Afterwards, the activity concentration stayed altogether at a low level of < 15 Bq/kg, of which the most important food fish of the Northern Pacific, namely pollock measured less than 10 Bq/kg (total cesium). Cesium activity values throughout the investigation period were for the above mentioned fish mostly lower than 50 Bq/kg with maximum of 144 Bq/kg (anchovy), 240 Bq/kg (cod), 270 Bq/kg (mackerel) and 670 Bq/kg (seabass), i. e. that only in one case the measured cesium activity concentration exceeded the limit allowed by the Japanese government for consumption as food at 500 Bq/kg. The results of measurements of radioactive cesium carried out by the Japanese Fishing Agency (FA) on behalf of the Ministry of Agriculture, Forestry and Fisheries (MAFF) /3/ are summarized in Table 1.

For these fish species, I-131 was detectable only until mid-April and that with radiologically irrelevant activity concentration values.

**Table 1: Cesium activity concentrations in edible fish from Northern Pacific fishing grounds (data from FA /3/)***

<table>
<thead>
<tr>
<th>Species</th>
<th>Cs activity (Bq/kg)</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Mar - Apr</td>
</tr>
<tr>
<td>Cod</td>
<td>&lt;1.0 - 13</td>
</tr>
<tr>
<td>Pollock</td>
<td>&lt; 1.0 – 2.3</td>
</tr>
<tr>
<td>Seabass</td>
<td>2.2 – 48.3</td>
</tr>
<tr>
<td>Mackerel</td>
<td>&lt; 1.0 – 40</td>
</tr>
<tr>
<td>Anchovy</td>
<td>&lt; 1.0 – 170</td>
</tr>
<tr>
<td>Sardine</td>
<td>&lt; 1.0 – 41</td>
</tr>
<tr>
<td>Tuna</td>
<td>&lt; 1.0 – 33</td>
</tr>
</tbody>
</table>
3 CONCLUSIONS

On the basis of the demonstrated results of investigation of the contamination in the Northern Pacific sea environment it should be stated that no danger for people arises from consumption of the fish and seafood from the large pacific fishing grounds. No further rise in contamination is expected on the basis of the current data. Even if Cs activity in sand lance and flatfish was detected at up to about 15,000 Bq/kg and 1,600 Bq/kg in the coastal areas off Fukushima, which is significantly higher than the limit allowed by the Japanese government for consumption of fish at 500 Bq/kg. Nevertheless, this sea area around the Fukushima NPP is restricted for fishing.

4 REFERENCES

/1/ TEPCO: www.tepco.co.jp/en
/2/ MEXT: www.mext.go.jp/english
/3/ MAFF: www.maff.go.jp/e