Analysis of ^{137}Cs concentration in marine sediments near Fukushima nuclear power plants

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1. Introduction

When a severe accident occurs at a nuclear power plant, lots of radionuclides are released and most of them finally moves into the sea. The seawater generally flows into the open seas and, thus, the overall radioactivity of seawater near the accident place decreases in a short period [1,2]. On the other hand, the radioactivity of marine sediments would not easily decrease over time, because the sediment materials could adsorb the radionuclides relatively strongly.

It was reported [3] that the concentrations of ^{137}Cs in marine sediments would take approximately 0.4-26 years to decrease by 50% at several locations near the accident place in Fukushima, if only the mixing rates are considered. Such contribution to the decrease in radioisotopes is not negligible, on considering the half-life of ^{137}Cs. Meanwhile, marine organisms can also contribute to the decrease of radioactivity, because they can accumulate considerable amounts of radionuclides in their bodies [4,5]. Since undesirable increase in the radioactivity of marine environments will influence any relevant organisms, it is very important to understand the radioactivity changes of marine environments, especially for the marine sediments, to ensure the safety of sea foods.

In present paper, we introduced the data analysis results, which were recently published [2], on the changes in ^{137}Cs radioactivity for the marine sediment samples near Fukushima nuclear power plants. In addition, we also mentioned the effect of the water content on the ^{137}Cs radioactivity in sediment samples.

2. Methodology of the data analysis

The ^{137}Cs radioactivities (per unit mass of sample) of sediment samples from the ocean near the FDNPP were analyzed. Radioactivity data were obtained from the Nuclear Regulation Authority (NRA) webpage [6]. TEPCO monitored and announced the radioactivity in the marine sediment near the FDNPP, and NRA published their data (about two years from May 2012) including the dry weight of each marine sediment sample divided by its wet weight and the radioactivity of each sample [6].

To analyze the TEPCO data, six sites were selected from 44 total sampling sites while considering three criteria: (1) average ^{137}Cs radioactivity more than 80 Bq/kg; (2) high variances in water content over time of marine sediments samples; and (3) water contents higher than the average water content estimated from the entire TEPCO data. The data of ^{137}Cs radioactivities and water contents were analyzed for the marine sediments sampled from May 2012 to April 2014 at the six sites.

Fig. 1 shows monthly average ^{137}Cs radioactivities in marine sediment samples obtained for two years at the sampling sites near the FDNPP. The ^{137}Cs radioactivity decreased over time, from 3.47×10^2 Bq/kg to 2.96×10^1 Bq/kg on the trend line, indicating the average decrease rate of 4.53×10^{-1} Bq/(kg·d). For the trend line, the R^2 and p-value were calculated as 0.3237 and 0.0022, respectively; the correlation between the ^{137}Cs radioactivity and time showed statistical significance.

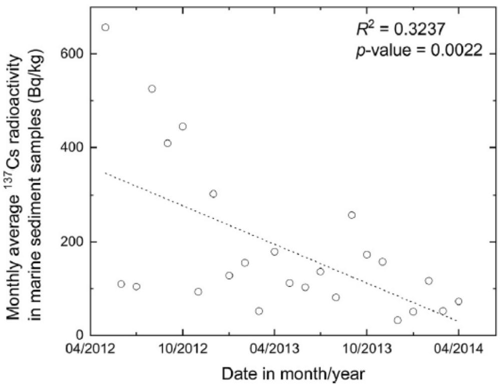

Fig. 1. Monthly average ^{137}Cs radioactivity in marine sediment samples obtained from 6 sampling sites near the FDNPP from May 2012 to April 2014 [2].

Fig. 2 shows a correlation between the relative water contents and the ^{137}Cs radioactivities in marine sediment samples obtained at six sampling sites near the FDNPP from May 2012 to April 2014. The relative water contents were distributed between 0.3 and 2.4, while the ^{137}Cs radioactivity varied from almost 0 to 2,000 Bq/kg. As the relative water content increased, the ^{137}Cs radioactivity increased on the trend line with R^2 of 0.3997, although the data points were scattered. The p-value of the trend line was almost zero and showed statistical significance in the correlation between two variables. This result suggested that the water content may relate to the ^{137}Cs radioactivity in the sediments [7,8].

Fig. 3 shows the relative monthly average water contents (RMAWCs) in the marine sediment over time, where the RMAWC is defined as in Equation (1). From May 2012 to April 2014, the RMAWC decreased by

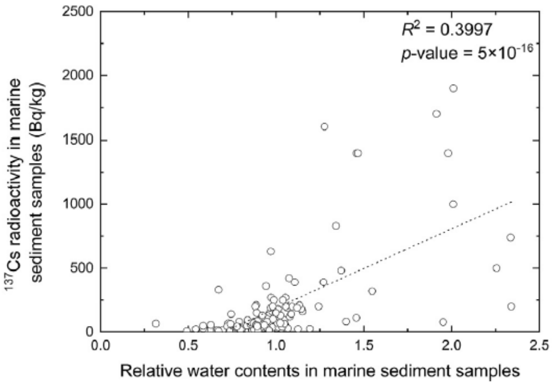

Fig. 2. Relationship between relative water contents and ^{137}Cs radioactivities in marine sediment samples obtained from six sampling sites near the FDNPP from May 2012 to April 2014 (average water content: 25.7% at a relative water content of 1.0) [2].

2.62×10^{-1} (more than 10% of the initial value) in total on the trend line. The correlation coefficient (R^2) and p-value of the trend line were calculated as 0.2313 and 0.0173, respectively. The p-value showed statistical significance in correlation between the RMAWC and time.

(RMAWC) = (Monthly average water content) / (Average water content for total sampling period) (1)

The water content decrease over time seemed to be an unusual phenomenon that could have resulted from the sudden rearrangement of the ocean floor structures due to a severe Tsunami. Although it was mentioned above that the water content decrease may relate to the decrease of the ^{137}Cs radioactivities in the marine sediments, no clear reasons based on the sediment data reported had been found until now.

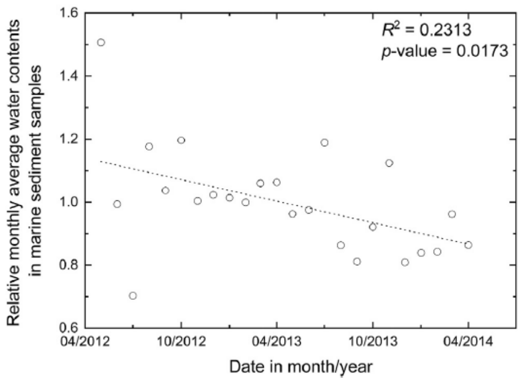

Fig. 3. Relative monthly average water contents in marine sediment samples obtained at six selected sampling sites near the FDNPP from May 2012 to April 2014 (average water content: 25.7% at a relative water content of 1.0) [2].

3. Summary

Radionuclides can be easily adsorbed to the sediments, while those dissolved in the water spread and widely with the water flow. According to the data analysis, the average ^{137}Cs radioactivities in the marine sediments of the ocean near the FDNPP generally decreased over time. This can be understood as the diffusion and spread of ^{137}Cs in the oceans due to nearby currents.

For the sediment near the FDNPP, the ^{137}Cs radioactivity increased mostly as the water content increased, and the total ^{137}Cs radioactivity decreased by 91.5% of the initial ^{137}Cs radioactivity (from May 2012 to April 2014). It was also found for the sediment near the FDNPP that the RMAWC change contributed 51.2% of the average rate of the ^{137}Cs radioactivity decrease. For marine sediments, the water content change is recommended to be the probability of the ^{137}Cs radioactivity change. For the analysis of radioactivity change of marine sediments, it is important to consider the change of water content values for the precise evaluation.

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