Quantification and Evaluation of the Strontium-90 Concentrations in soil of Fukushima Prefecture before and after the Fukushima Daiichi Nuclear Accident

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Abstract and background

To precisely understand the status of scattered strontium-90 after the 2011 accident at the Fukushima Daiichi Nuclear Power Plant (NPP), the measurement of the soil samples collected both before and after the day of the accident from the same sampling locations is necessary. However, very few reports have investigated the background contaminant data before the accident even though several studies have been conducted to investigate the effects of the F1-NPP accident. To address the lack of the passed ^{90}Sr information and reestablished baseline, this study focuses on the stored topsoil samples that are collected from the same sampling locations from the Fukushima Prefecture before and after the F1-NPP accident, which are analyzed for obtaining the ^{90}Sr concentrations. The results of our investigation exhibited that the ^{90}Sr concentrations in the Fukushima Prefecture soils ranged from 0.2 to 20.4 Bq/kg in the samples that were collected before the accident and from 1.37 to 80.8 Bq/kg in the samples that were collected after the accident from identical sampling locations. Further, the soil samples that were collected from 30 out of 56 locations displayed significant differences in terms of concentrations before and after the accident. In addition, the relations between the ^{90}Sr concentrations and the soil properties of the samples (organic content, pH, water content, and composition) were investigated, and it was found that the organic content and water content had a positive correlation with ^{90}Sr concentrations and, in contrast, the sandiness was shown to have a negative correlation with Sr-90 concentrations. The depth characteristics were also investigated. The aforementioned results indicate that this tendency would be observed even in the future.

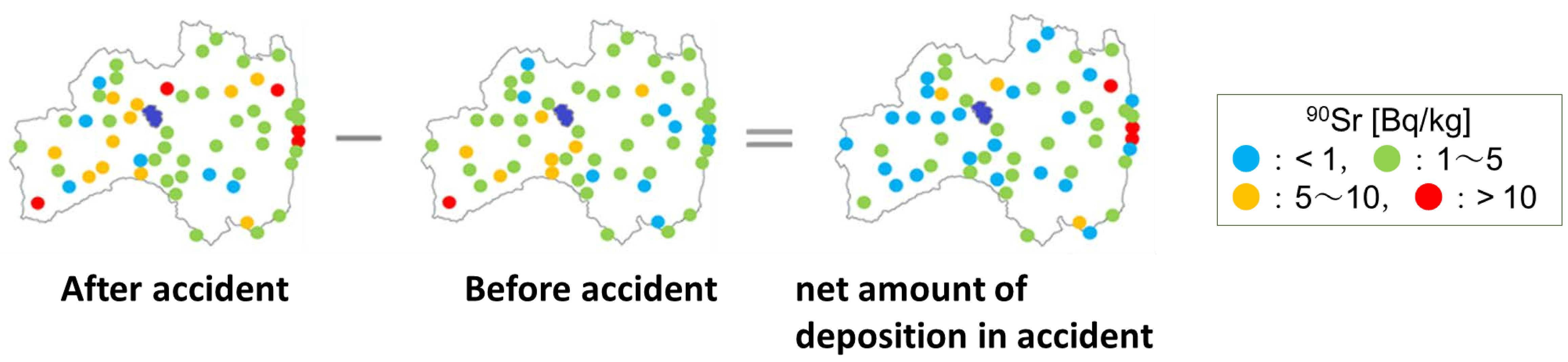

Figure 1 Comparison of ^{90}Sr concentrations on surface soil between before and after Fukushima Dai-ichi nuclear power station accident in whole area of Fukushima prefecture

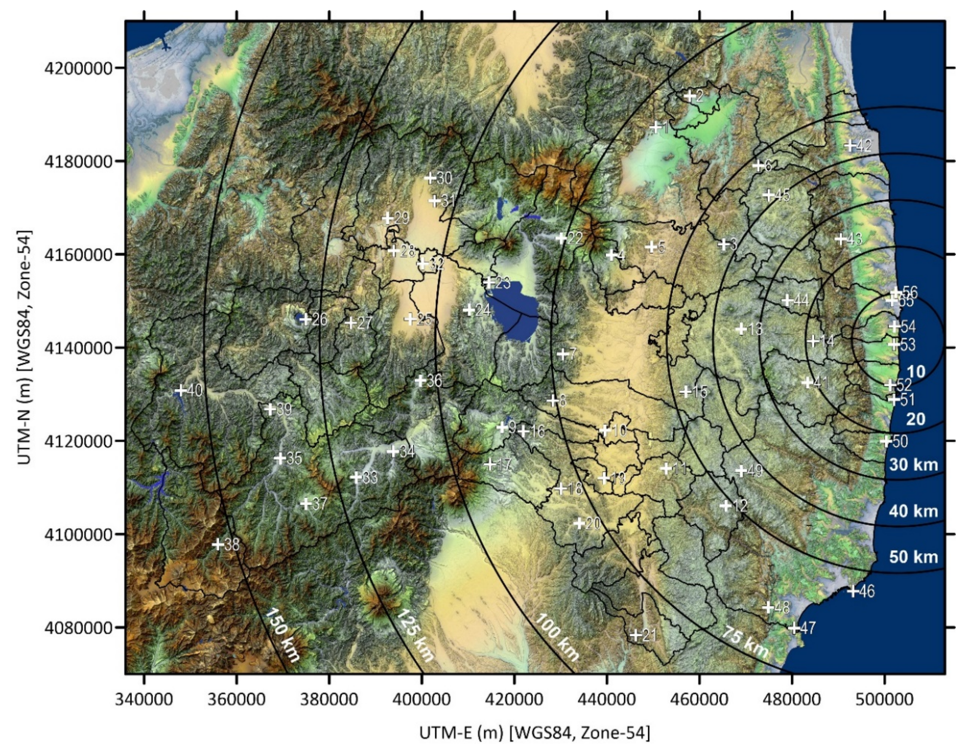

Figure 2 The sampling was conducted at 56 points which were chosen from whole area of Fukushima prefecture.

Results

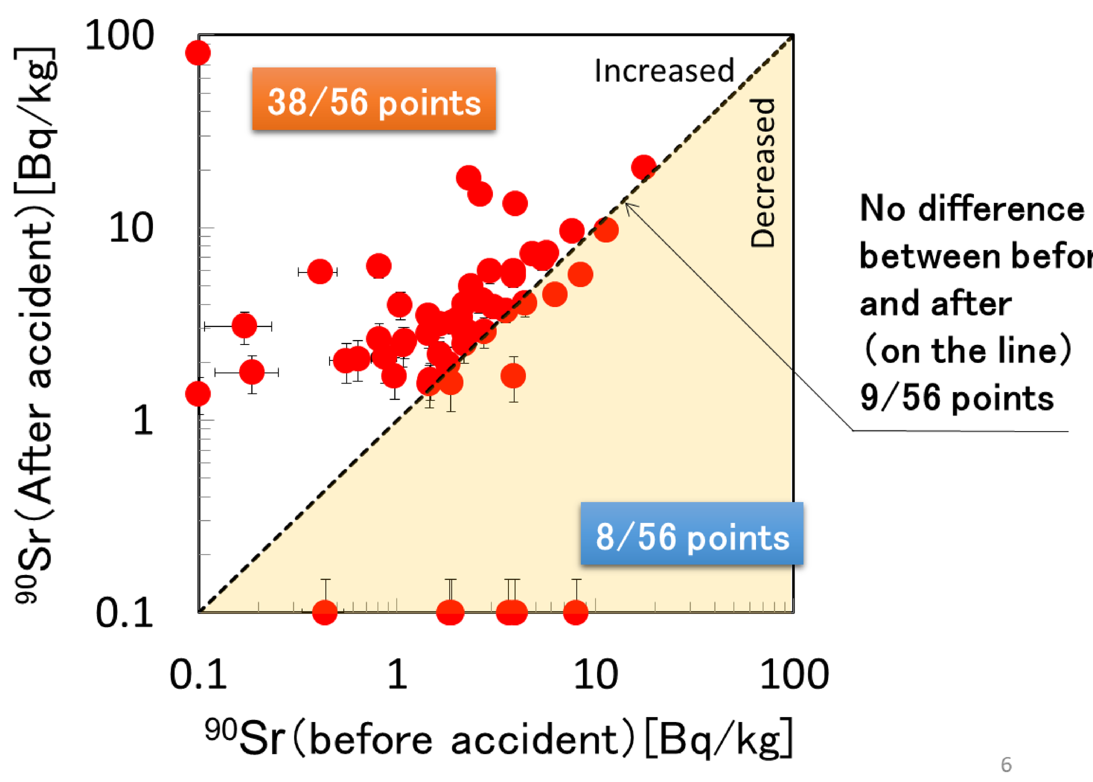

Figure 3 The variation of ^{90}Sr concentration in soils (at same GPS location) of Fukushima –pref between before and after accident of Fukushima NPP (2005 and 2011).

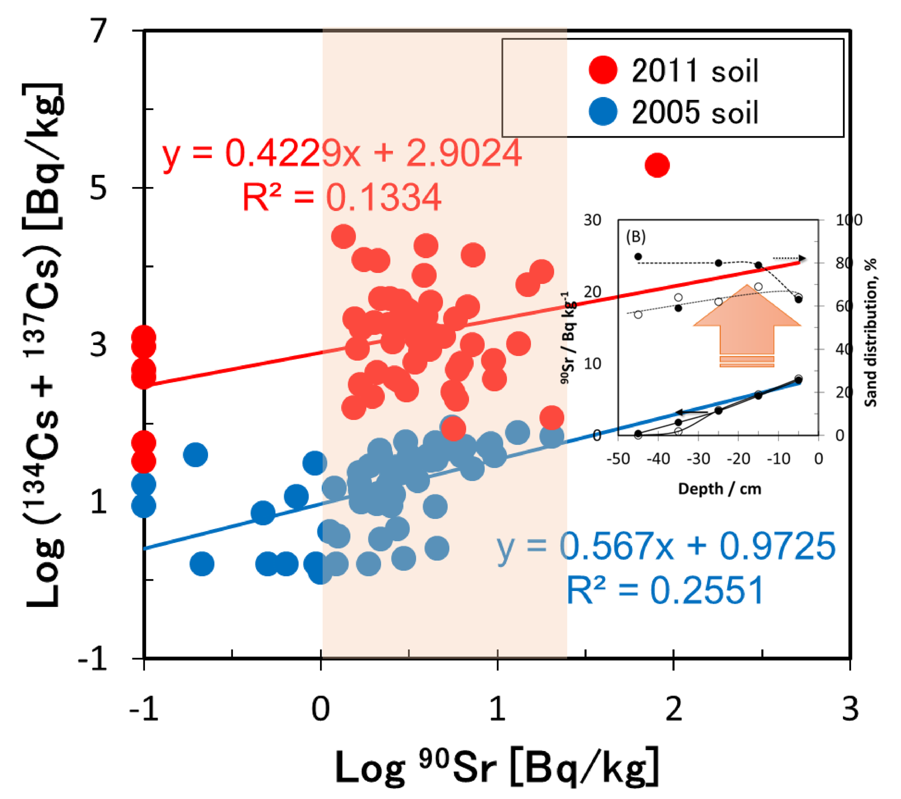

Figure 4 Relationship between ^{90}Sr concentration in soil and $^{(134+137)}$Cs concentration at whole Fukushima prefectural region before and after accident of Fukushima NPP.

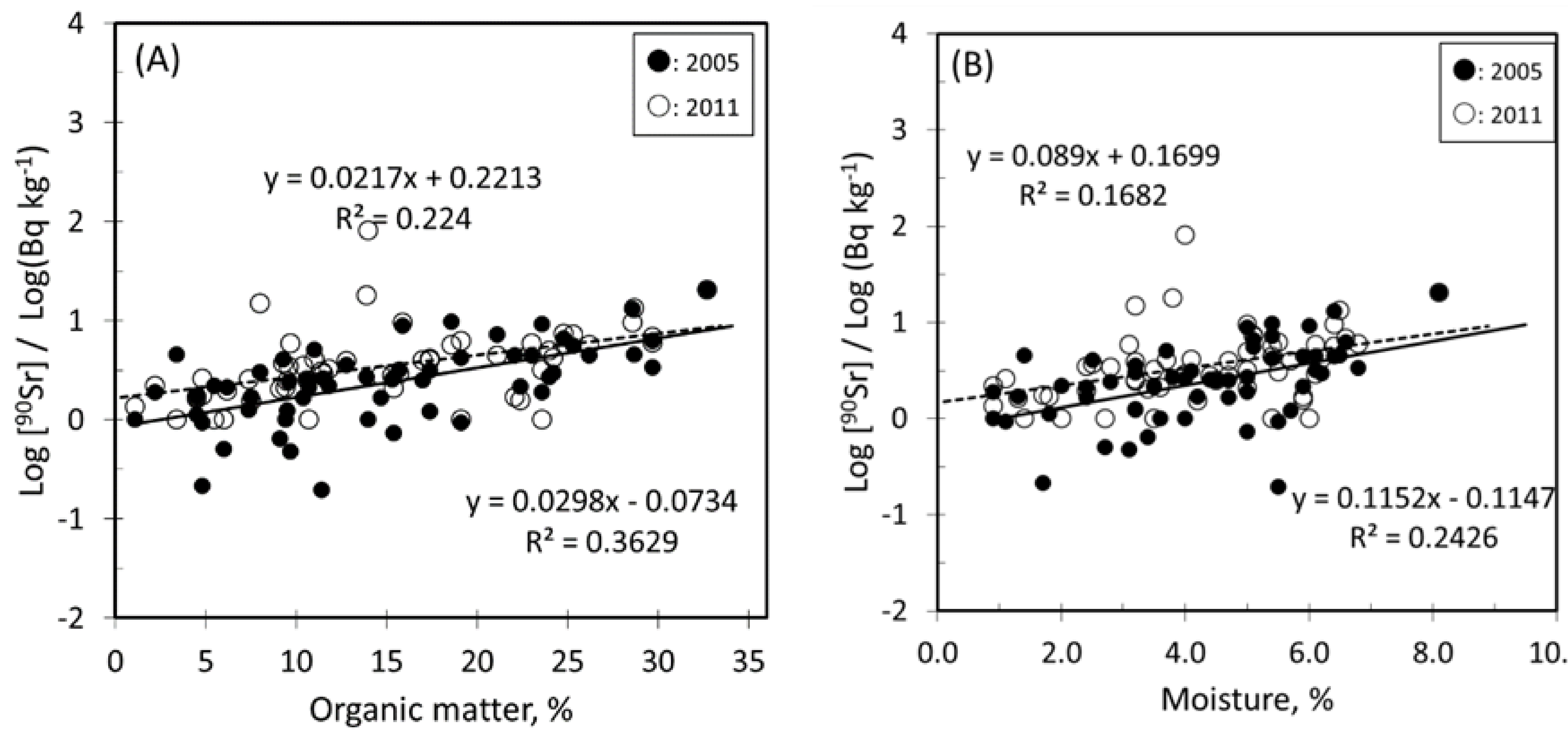

Figure 5 The impact of organic matter (A) and the moisture (B) on ^{90}Sr concentration on the surface soil and the comparison between before accident (2005) and after accident (2011) of Fukushima NPP in whole Fukushima prefectural region .

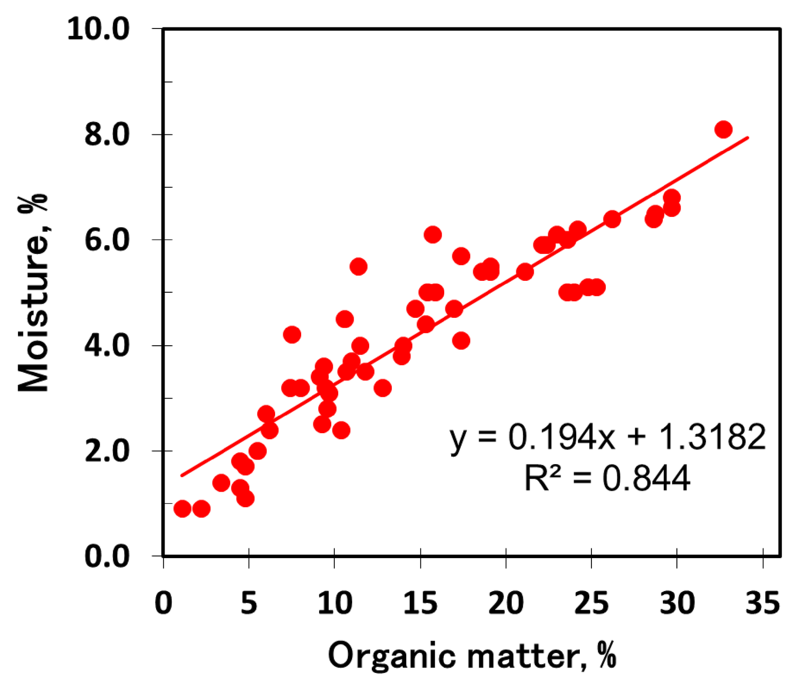

Figure 6 The relationship between the organic matter and moisture in collected soils.

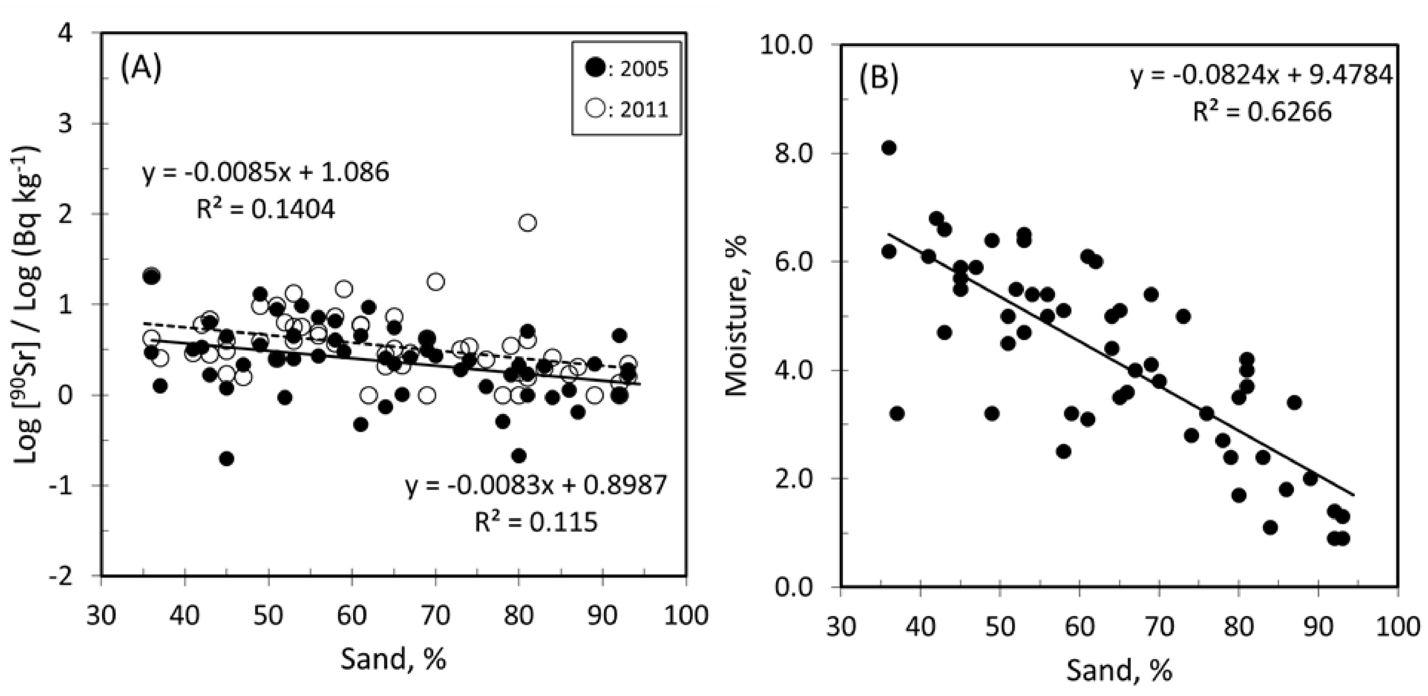

Figure 7 The impact of sand distribution on ^{90}Sr concentration in the surface soil between before accident (2005) and after accident (2011) of Fukushima NPP in whole Fukushima prefectural region (A); and the relationship between sand and moisture (B).

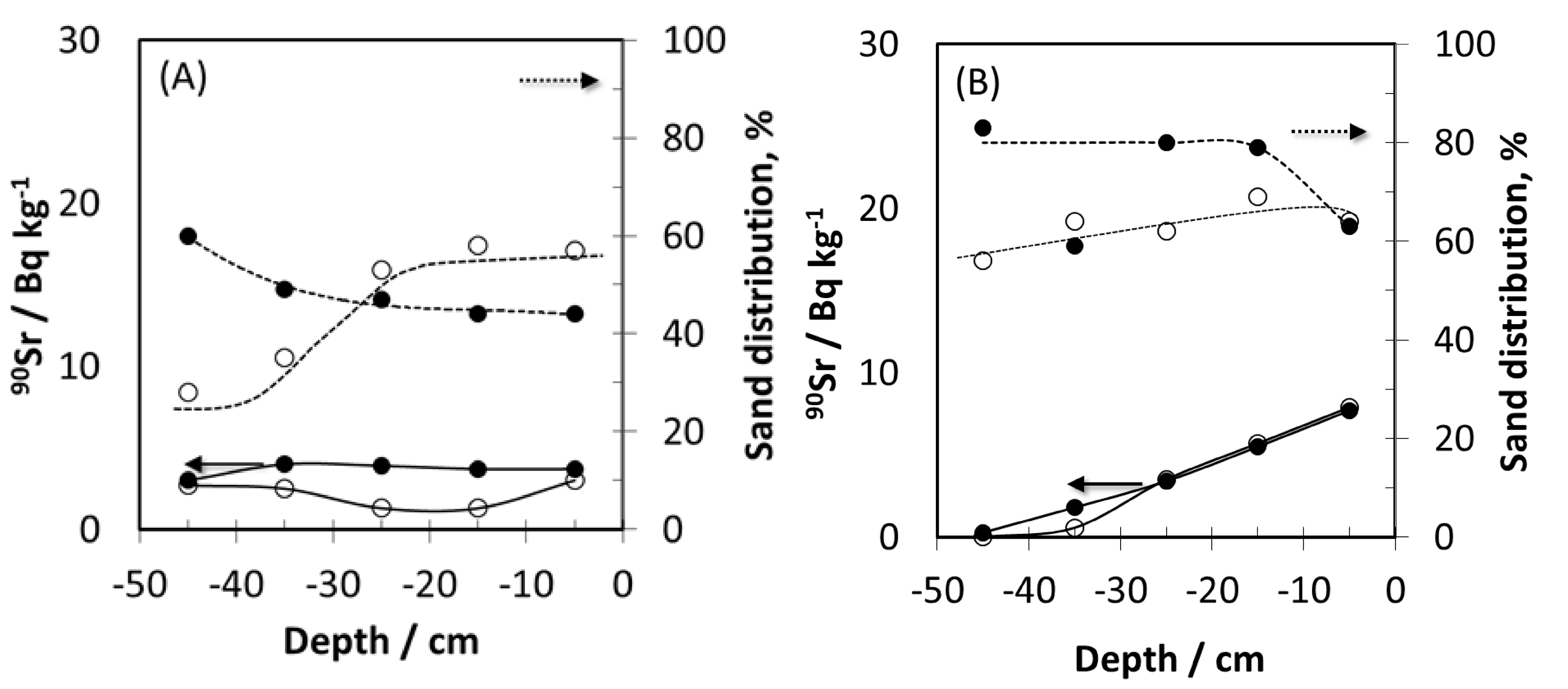

Figure 8 The distribution of ^{90}Sr concentration in the depth direction of soil. (A) Eastside of Fukushima pref., (B) Center region of Fukushima pref.

Conclusion

The ^{90}Sr concentrations before the F1-NPP accident (2005) were in the range of 0.2 to 20.4 Bq/kg (RSD 5.3%). These ^{90}Sr concentrations were within similar concentration ranges as compared to those observed in other areas of Japan. It was observed that the ^{90}Sr concentrations in soil tended to increase in the order of the eastern, central, and western regions and that they were particularly high in the southwestern part in Fukushima before the F1-NPP accident (2005). The ^{90}Sr concentration in soil that was collected from the same locations after the accident (2011) was in the range of 1.37 to 80.8 Bq/kg (RSD 9.6%). By comparing the soil samples that were collected before and after the accident, the number of locations at which the ^{90}Sr concentrations clearly increased was 38 out of 56 locations, with a maximum increase of 80 Bq/kg. All the soil samples that were collected before and after the accident exhibited higher radioactive Cs concentrations as compared to the ^{90}Sr concentrations, and the $^{(134+137)}$Cs/^{90}Sr ratio before the accident (2005) was slightly higher than the ratio after the accident. Furthermore, there was no correlation between the pH of soil and the ^{90}Sr concentrations. Meanwhile, there was a correlation between the organic content and the water content in topsoil, and the ^{90}Sr concentrations tended to increase as the water content increased, and this tendency was present in the soil samples that were collected before and after the accident. Further, the ^{90}Sr concentrations decreased as the percentage of sand in soil increased. In the eastern region, ^{90}Sr was detected at almost constant concentrations regardless of the depth, whereas it was revealed that ^{90}Sr was detected in the surface layer in the central and western regions.

To summarize, the deposition tendency of ^{90}Sr before (2005) and after (2011) the accident was similar depending on the organic content, water content, and sandiness (in other words, clay properties). Additionally, in terms of the depth dependency, although some regional characteristics were observed, ^{90}Sr, for the most part, remained in the topsoil in the central and western regions of Fukushima, whereas it tended to disperse at a constant rate in the eastern region. Because a similar behavior was observed both before and after the accident, it can be considered that this surface deposition tendency will continue in the future if there is no new ^{90}Sr release or decontamination of the soils. Further, it is expected that the ^{90}Sr concentrations will be attenuated based on the physical half-life.

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