Cod: 4.1006

ENVIRONMENTAL DISCHARGE OF PERFLUOROALKYL SUBSTANCES BY TWO GREAT EARTHQUAKES IN JAPAN. THE GREAT EAST JAPAN EARTHQUAKE IN 2011 AND THE KUMAMOTO EARTHQUAKE IN 2016.

E. Yamazaki[1], N. Yamashita[1], S. Taniyasu[1], Y. Miyazawa[2], T. Gamo[3], K. Kannan[4]

[1]*National Institute of Advanced Industrial Science and Technology (AIST), 16-1 Onogawa, Tsukuba, Ibaraki, Japan*

[2]*Japan Agency for Marine-Earth Science and Technology, 3173-25 Showamchi, Kanazawa-ku, Yokohama 236-0001, Japan*

[3]*Department of Chemical Oceanography, Atmosphere and Ocean Research Institute, The University of Tokyo, 5-1-5 Kashiwanoha, Kashiwa, Chiba 277-8564, Japan*

[4]*New York State Department of Health and Department of Environmental Health Sciences, State University of New York, Albany, NY 12201-0509, USA*

Introduction

Perfluorooctanesulfonate (PFOS) and perfluorooctanoate (PFOA) were first detected in open ocean water collected in 2002 from the Eastern Pacific Ocean. In order to determine the mechanism of global transport and distribution of perfluoro alkyl substance (PFASs), ocean monitoring of PFASs was initiated in 2002. During the last 15 years of open ocean survey, PFASs were considered as chemical tracers of global ocean cycling, and as a chemical markers of exposures in people in disasters such as world trade center collapse in the U.S.
A similar disaster occurred in Japan on March 11th, 2011, namely The Great East Japan Earthquake (EQ 3.11). The disaster of earthquake followed by tsunami and fire has resulted in serious environmental problems in Japan. The disaster started at 14:46, JST, on March 11, in the northeastern region of Japan. From the currently available estimation (May 7, 2011), more than 14,000 people have died and more than 10,000 are missing. The minimum number of completely destroyed buildings was 59,000.
The earthquake was just a trigger, which was followed by tsunami (more than 90% people were drowning) and fires that caused the "catastrophe". The earthquake on March 11 (EQ 3.11) in Japan had specific combination of three calamities; the strongest (M9.0) earthquake recorded, the highest (almost 10 m) tsunami recorded and followed by serious disaster of nuclear power plants in Fukushima prefecture.

After five years, another earthquake happen in Kumamoto and Oita prefectures in Kyushu Island in Japan. The first attack by earthquake (M6.5) happen at 21:26, JST, on April 14, in Kumamoto and followed by the earthquake (M7.3) at 01:25, JST on April 16, its biggest earthquake in the western part of Japan after 1995. The special phenomenon of "the 2016 Kumamoto earthquake (KEQ 4.14)" is continuous shake even three week after its happen. Total number of earthquakes recorded after April 14 was 337 by end of April.

In this report, we provide comprehensive understanding of environmental discharge of PFASs because of EQ3.11 and try to make interpretation about similarity and difference between environmental disturbance of PFASs between EQ3.11 and KEQ4.14.

Materials and Methods

Several environmental samples including, soil, sediment, ash, river water, seawater and tsunami discharged pool-water were collected from Miyagi, Iwate, Fukushima, Ibaraki and Chiba prefectures which were hit by the EQ 3.11 and consequent tsunami-related damages. Sampling was conducted within one month after the EQ 3.11. Ten to 500 ml of water samples were analyzed by following the modified International Standard Method (ISO25101:2009, published in March 1st) described elsewhere and the Japanese Industrial Standard Method (JIS K0450-70-10:2011, published in March 22nd). Similar environmental samples were collected from near to the disaster region of KEQ 4.14 and investigated. Seven perfluorinated sulfonates, fourteen perfluorinated carboxylates, FOSA, N-EtFOSA, NEtFOSAA, saturated fluorotelomer carboxylates, unsaturated fluorotelomer carboxylates and fluorotelomer alcohols were analyzed. Overall recoveries of above chemicals through the analytical procedure ranged from 81% to 125%.

Results and Discussion

Significant residues of PFASs were observed in both coastal water and tsunami-derived water pool located about 500 m from the coast of Tohoku region. There was no considerable difference in PFASs concentrations between seawater and tsunami-derived water pool. It suggests that tsunami resulted in mixing up of PFASs between inland and coastal waters. A similar trend was found for PFASs in coastal seawater and tsunami-derived water pool remained in area B located around 1 km from the coast. However, area A, located 3 km from the coast, showed relatively higher PFOA concentration compared to seawater. This result suggests that PFASs concentrations and compositions can be useful to evaluate the disturbance of chemicals and the influence of tsunami. It is considered that these findings relate to the physical mechanism of the tsunami. After tsunami, the area covered by the wave diminished gradually over a period of few hours, which suggests that the strength of tsunami backwash was minimal at the edge of the tidal wave, as it reached inland areas, and thus, the chemical dispersal would be expected to be higher in coastal areas than inland areas. This finding suggests that the residue level and type of chemicals disturbed by the tsunami dependent on the water solubility of chemicals, altitude above the sea level, and location and distance from the coast.

As interesting remark, it can be mention as “big clean-up of coastal pollution because of sweeping away by Tsunami”. It is also worth to mention that, the disaster area with fire had relatively higher concentrations of PFASs compared to the areas without fire. Although it would have been to have the background contamination status before EQ 3.11 in both locations, some lower fluorinated chemicals can be formed from fire-related activities.

Not only monitoring study but also a numerical model was used to simulate the possible transportation mechanism of PFOS and PFOA from the coast to the open ocean after EQ3.11. In this respect, a supercomputer simulation of eddy resolving ocean reanalysis product (JCOPE2) was developed at JAMSEC. Detailed information on the model, and the type of formula used for the numerical simulation are reported in the literature. A big data base about EQ3.11 was reported already (Environ. Sci. Technol. 2015, 49, 11421−11428).

Although the environmental samples collected from KEQ4.14 still under investigation, above findings from EQ3.11 suggested remarkable point that similarity and difference between two big earthquakes with and without tsunami. Ironically, the accidental emission of PFASs caused by EQ 3.11 and the tsunami have revealed the first clear evidence of long-range transportation by water currents from land to ocean, and the quantitative dilution mechanism of these water soluble persistent pollutants on a global scale. Here we can report useful findings to understand environmental disturbance because of two historical earthquakes in Japan.

Acknowledgement

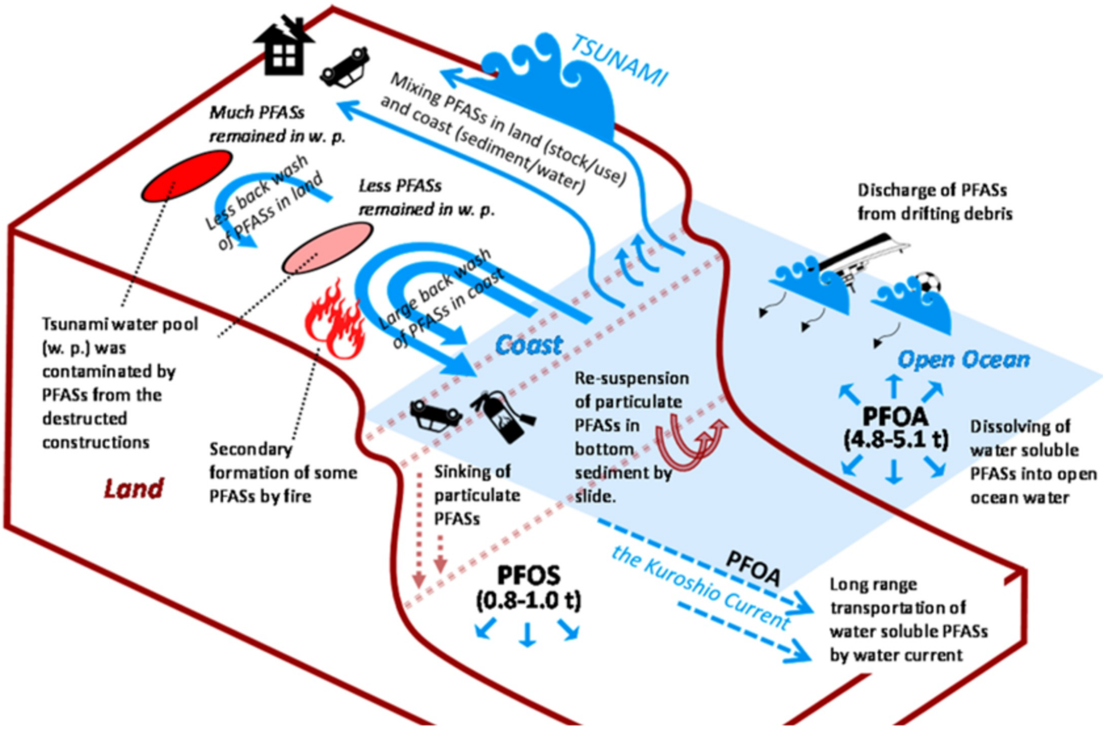
Authors express sincere thanks to those who provided local support in the disaster areas and pray for their quick recovery.
The disaster in Japan has not ended yet. In 2015, four years after EQ3.11, 228 800 people remain evacuated from their homes. KEQ 4.14 is still continued and 19 509 people remain evacuated from their homes.
All of your support and concerted action about damaged regions and people are key to recovery and regeneration.

Contact address : nob.yamashita@aist.go.jp.

References

1. Taniyasu, S., Kannan, K., Horii, Y., Hanari, N., Yamashita, N. 2003. Environ. Sci. Technol., 37, 2634-2639

2. Yamazaki E., Yamashita N., Taniyasu S., Miyazawa Y., Gamo T., Ge H., Kannan K. 2015. Environ. Sci. Technol. 49, 11421−11428



Schematic illustration of perfluoroalkyl substance emissions from land to ocean following the earthquake EQ 3.11. *(from Environ. Sci. Technol. 2015, 49, 11421−11428)*