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Effects of heavy elements in the sludge conveyed by the 2011 tsunami on human health and the recovery of the marine ecosystem

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ABSTRACT

The 2011 tsunami not only caused significant damage, but also drew a large amount of sludge from the bottom of the sea. This may have exerted negative effects on human health. In order to evaluate changes in elemental concentrations in the body before and after the tsunami, we collected long hairs from victims of the disaster. Furthermore, sludge and plant samples were collected from three prefectures. The sludge samples on land were found to be still contaminated with heavy elements. The concentrations of heavy elements in the soils and plants gathered from the same tidelands decreased after one year. In hair analyses, no clear changes have been observed in heavy element concentrations measured before and after the tsunami. However, the concentration of some essential elements, such as Cu, Ca and Mg, showed a decreasing tendency after the tsunami.

1. Introduction

The massive tsunami that stuck the East coast of the Tohoku district of Japan on March 11, 2011 resulted in severe damage. It also brought a large amount of sludge piled on the bottom of the sea up to the land. It is known that the sediments of Japanese bays are contaminated with toxic heavy elements [1]. We have previously reported the results of studies of the negative effects of sludge on the environment in the Sanriku district [2,3]. We gathered sludge and plant samples over a wide area along the shore. Both the sludge piled on land and plants growing in these areas were found to be contaminated with heavy elements [2,3].

It is anticipated that such elements would exert negative effects on human health. Inhalation of dried sludge is also worrisome. In order to evaluate changes in the elemental concentrations in the body before and after the disaster, we collected long hairs from victims of the disaster. Sludge samples were collected from the Miyagi and the Fukushima prefectures. In addition, soil and plant samples were again collected on October 10, 2012 from the same tidelands as those reported in Ref. [3] in order to evaluate changes in the concentrations of heavy elements over time. The hairs were analyzed using our previously developed standard-free method for evaluating untreated hairs [4]. The results are expected to provide information regarding elemental changes in the body before and after the tsunami.

2. Materials and methods

2.1. Sample collection

Sampling of sludge and plants was performed eight times: on July 20, August 14, August 31, September 3, September 17 and November 10 in 2011 and March 3 and October 10 in 2012, in the Aomori, Iwate, Miyagi and Fukushima prefectures. A total of 102 sludge samples were collected. The results of the samples gathered before September 2011 have been previously reported [2,3]. Fig. 1 shows the locations of the sampling spots in the present study. Among these 17 samples, No. 1 and 2 were collected on November 10, 2011 and other samples were collected on March 3, 2012. Ten soil and 21 plant samples were collected again after one year (October 10, 2012) from the Tsugaruishi and Orikasa tidelands, and the plant samples were tabulated in Table 1 with their botanical names.

Twenty-nine human hair specimens were collected from sufferers living in the cities of Ofunato and Miyako in January and February of 2012. As hair is known to grow approximately 1 cm a month, the point corresponding to March 11, 2011 can be estimated from

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the period of sampling. Therefore, hairs longer than 10 cm were expected to provide meaningful information. The measurements were performed by cutting the hair every 1 cm and irradiating the tip of each hair with a proton beam.

2.2. Target preparations

The soil samples were placed in a sterilizer and dried at 105 °C. Palladium powder (Pd–carbon) has been added as an internal standard at 1 wt.% concentration [5]. The samples were homogenized well in an agate mortar and less than 1 mg of the mixture was placed on a backing film (4 µm thick Prolene film) and fixed with a 1% collodion solution. The plant samples were treated in accordance with the internal-standard method combined with a chemical-ashing method, where indium solution has been added to the sample at 1000 ppm concentration, and the samples were dissolved in nitric acid in a microwave oven [6].

2.3. Irradiation and measurement conditions

The targets were bombarded with a 2.9 MeV proton beam extracted from a small-sized cyclotron at Nishina Memorial Cyclotron Center, and the emitted X-rays were simultaneously measured with two Si(Li) detectors [7]. X-ray absorbers were used for the No. 1 detector. 500-µm-thick Mylar film was used for the sludge and plant samples, while 300-µm Mylar was used for the hair samples. A specially designed absorber [8] developed for the purpose of improving sensitivity for detecting heavy elements was also used for the soil samples. Estimated detection limits for toxic and trace elements concerned are tabulated in Table 2 for soil, plant and hair. Typical spectra of the soil samples obtained with a specially designed absorber are shown in Fig. 2 in Ref. [2].

3. Results and discussions

Fig. 2 shows the elemental concentrations in the soil samples containing sludge collected on November 10, 2011 and March 3, 2012, and their sampling spots are shown in Fig. 1. The soils No. 1 and 2 were obtained from Okawa in the Miyagi prefecture near the mouth of the Kitakami River where many lives were sacrificed. The other soils were gathered from the Southern side of the Miyagi prefecture and the Northern side of the Fukushima prefecture as shown in Fig. 1. In Fig. 2, the average values of the 73 sludge samples obtained before September 2011, which were previously reported [2], and those of 47 inland soils collected in the Iwate prefecture before 2008 are depicted by black and gray lines,

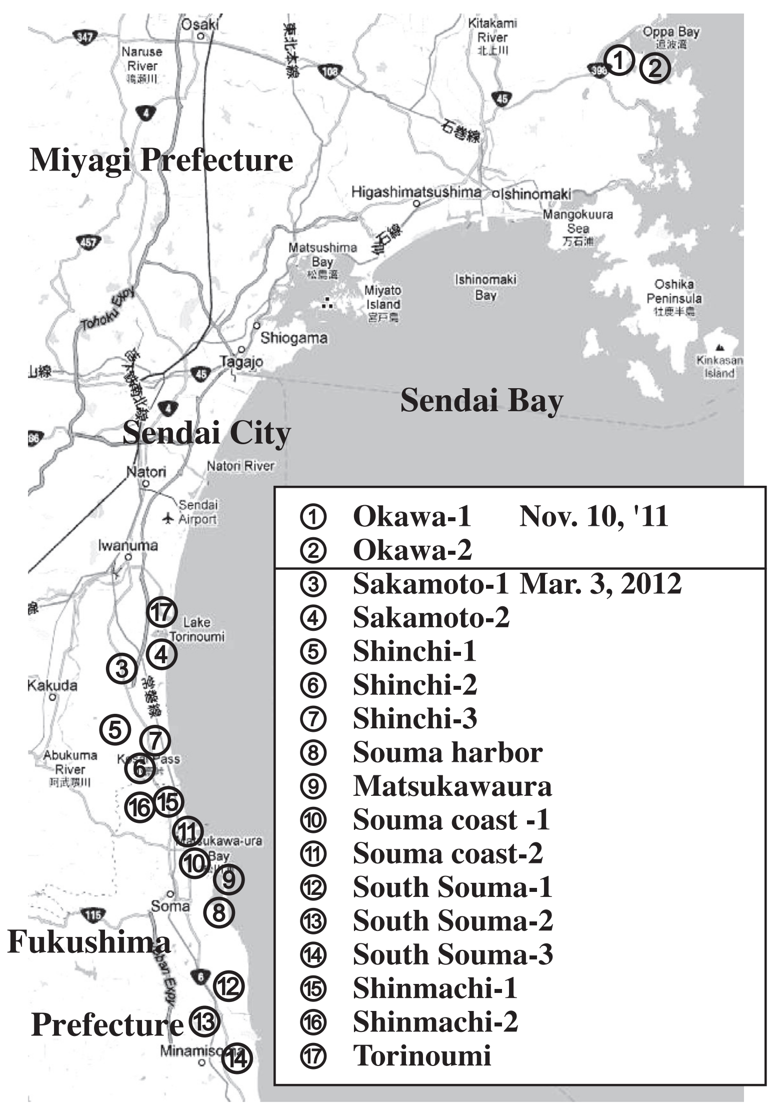

Fig. 1. Locations of the sampling spots of soil samples collected on November 10, 2011 and March 3, 2012.