Spatial and Temporal Distribution of Radio-Cesium in the Sediment of Tokyo Bay and Surrounding Rivers.

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1. Introduction

Tokyo Bay is very important water body in Southern Kanto region of Japan. The population of Tokyo Metropolitan area is about 13.19 million as of 2011 (Tokyo Metropolitan Government Website). Tokyo Bay is not only commercially important but also has environmental perspective. Many rivers empty into the Tokyo Bay. For example, Arakawa, Tamagawa and Sumidagawa rivers empty into Tokyo Bay near Tokyo. The Edogawa River empties into Tokyo Bay in between Tokyo and Chiba Prefecture. After the Fukushima incident in March, 2011, radio nuclides were spread out in atmosphere and in land-sediment. Radio-cesium can be used as a good tracer to distinguish the older sediment and newer sediment. Further this radio-cesium associated sediment could be used for the sediment transport indicator in Tokyo Bay and connected rivers.

Rivers play an important role in erosion as they are the primary carriers of transferring erosion products to the ocean. Understanding sediment transport in rivers and estuaries and their amount will improve the perception of many basic processes such as biogeochemical cycling of pollutants and nutrients, soil formation and their erosion (Allen, 2008).

According to Oura and Ebihara, 2012, after the FDNPP incident, a large amount of radioisotope materials were released to the environment. The contamination affected not only the areas around the reactor itself, but also a relatively large area of eastern mainland of Japan with Some specific areas became heavily contaminated.

In this study, the distribution of radio-cesium in the sediment of Tokyo Bay and the rivers of Arakawa, Edogawa and Sumidagawa which are mixed with Tokyo Bay will be investigated to understand the transportation mechanisms and fate of the contaminated sediment.

1.1. Objectives of the study

- To clarify the transportation and fate of the contaminated sediment.
- To clarify the impact of the particle size effect on the adsorption of radio-cesium.
- To observe the seasonal variation of diffusion and sedimentation in vertical direction by using the vertical profile results of the core samples.
- To know the relationship between land use and sediment flux, impact of water quality parameters on the distribution of radio-cesium.

2. Materials and Methods

2.1 Study Area and Samples

Sediments samples are collected from the Tokyo Bay, Arakawa River, Edogawa River and Sumidagawa River estuary area for the measurement of the Cesium 134 and Cesium 137 concentration. From Tokyo bay only surface sediment were collected from five stations named as Station-8 (N 35°33' 16",E 139°54' 20"), Station-13 (N35°29' 18" , E 139°54' 24"), Station-97 (N35°29' 16" , E 139°49' 07"), Station-98 (N35°33' 59" , E139°51' 21") and Station-99 (N35°37' 45", E140°00' 31") (Fig: 1) but from the rivers with surface sediment, core samples were also collected. There are seven sampling points (Station 1 to Station 7) in Arakawa river and eight sampling points (Station 8 to Station 15) in Edogawa river among them core samples were taken from Station 4 and Station 14 upper stream of Arakawa and Edogawa river respectively and also from station 7 and station 9 downstream of Arakawa and Edogawa river respectively. In Sumidagawa River estuary there were 24 sampling points. The samples are collected almost every month from Tokyo Bay and from rivers every three months interval.

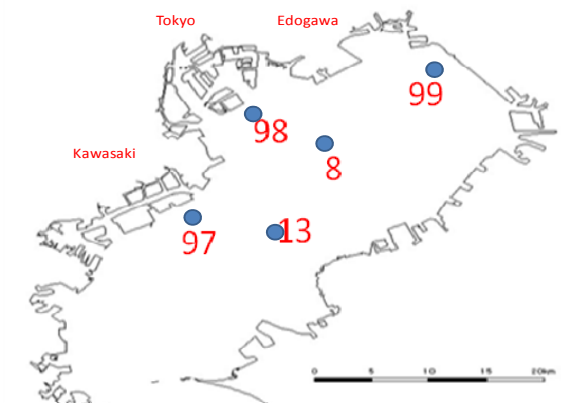

Figure 1: Sampling sites of Tokyo Bay

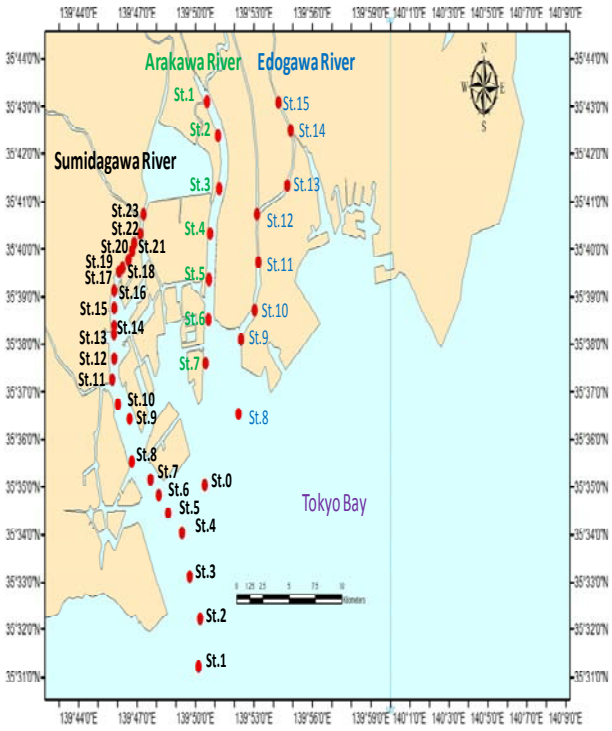

Figure 2: Sampling sites in all three rivers

2.2 Laboratory Procedure

The sediment samples were oven dried for 20-24 hours and then kept in the polyethylene bag (Ziploc) for radio cesium activity determination. The sediment sample weight varies from 5 to 180 gm. The radio cesium concentration was measured as a unit of Becquerel per kilogram (Bq/kg) in dry weight. The radio cesium was measured by using EG & G ORTEC GAMMA-X^{R} HPGe (High-purity Germanium) Coaxial Photon Detector along with Seiko EG & G Spectrum Navigator as a software tool.

The particle size of the sediment samples were analyzed by using a laser diffraction particle size analyzer (SALD-3000S) produced by Shimadzu Co. Japan, with the compatible software (Wing SALD-3000S).

2.3 Numerical Modeling for Diffusion and Advection

Governing equation for diffusion

$$\frac{\partial c}{\partial t} = k_z \frac{\partial^2 C}{\partial z^2} - \lambda(t) \quad \text{.....1}$$

Governing equation for advection

$$\frac{\partial c}{\partial t} = -\frac{\partial uC}{\partial z} - \lambda(t) \quad \text{.....2}$$

where, K_z= diffusion coefficient, c denotes the concentration of cesium, z denotes depth, t denotes time, u= sedimentation rate, λ= decay constant of cesium. The vertical profile was 38 cm. long and the depth difference was 2 cm. times difference was 744 hours or 1 month, three layers were used to calculate the diffusion and advection. It was assumed that no cesium added from the water column and the result of first sample which was taken in September, 2012 was the initial concentration and then compared with other time concentration.

2.4 Particle Size Analysis

The particles were mainly classified into three type clay, silt and sand in this study and their classification system followed as Wentworth Scale (Table-1).

Table 1: Type and size range of Particle size

Type of Particles	Size Range (mm)	Size Range (μm)
Sand	0.06-2.0	60-200
Silt	0.0039-0.06	3.9-60
Clay	<0.0039	<3.9

2.5Suspended Solid (SS) Flux experiment:

Water samples of Edogawa River from Noda bridge point after each large rainfall event were collected to measure the suspended solid concentration and radio-cesium concentration and thus the relationship of water level and the SSC (suspended solid concentration) was made to estimate the yearly total suspended solid flux and thus cesium flux.

The water samples were filtered in the experiment room using suction filtration machine (Figure-8) and used the Whatman Glass Microfiber filters GF/F, diameter is 90 mm and the pore size of the filter is as standard of 0.45-μm.

3. Results and Discussion3.1 Cesium (Cs^{134} and Cs^{137}) distribution in Tokyo Bay, Arakawa, Edogawa and Sumidagawa River.

In case of the distribution of radionuclide in the Tokyo Bay sediment the result shows that the concentration in all five stations ranging from 5 to 160 Bq/kg and 0.71 to 80 Bq/kg in case of Cs^{137} and in case of Cs^{134} respectively. There was same trend of low concentration except in the month of October 2012 in station 98 which was Northern part of Tokyo Bay (Figure-3).

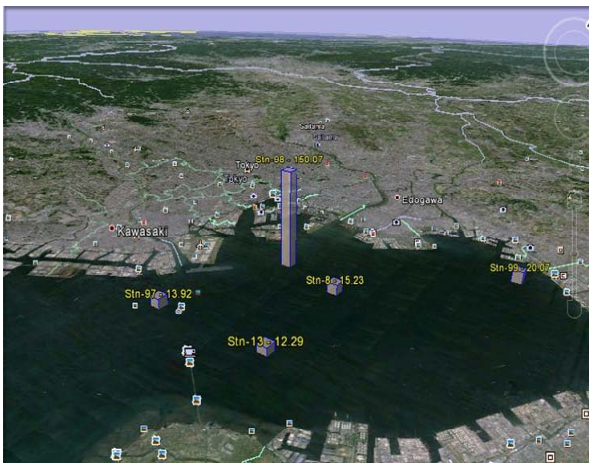

Figure 3: Spatial Distribution of Cesium of Oct, 2012 in Tokyo Bay

3.2 Vertical Profile of Cesium (Cs^{134} and Cs^{137}) Distribution.

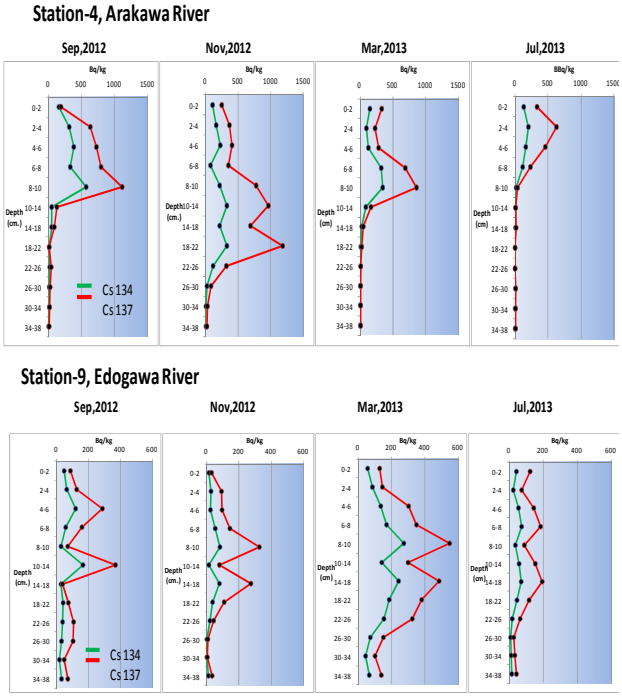

Figure 4: Vertical Profile of Cesium Distribution in Arakawa and Edogawa River.

Figure-4 shows the time series of vertical profile result from station-4 of Arakawa River and station-9 of Edogawa River. The cores total length were 38 cm. the cores were divided into the 12 layers first 5 layers width were 2 cm. each and 6 to 12th layer the cores were cut into 4 cm width.

In Arakawa River, sedimentation was dominant in all seasons (R^2 value was 0.698 for sedimentation whereas R^2 value was 0.256 for diffusion). In Edogawa River, diffusion was dominant in summer of wet season (R^2 value was 0.964 for diffusion whereas R^2 value was 0.654 for sedimentation). In Sumidagawa River, sedimentation and diffusion were almost same level. It was observed that, total cesium concentration ($^{134}Cs+^{137}Cs$) was high where the silt contents were high for example in Arakawa River the silt content was highest 76% in station-7, the total cesium concentration ($^{134}Cs+^{137}Cs$) was highest 449 Bq/kg. Similarly in Edogawa River the silt content was highest 79% in station-15, the total cesium concentration ($^{134}Cs+^{137}Cs$) was highest 1856 Bq/kg.

4. Conclusion

The cesium concentration in Tokyo bay was not changing rapidly and almost in low concentration. However in case of river beds, it showed variations from 2012 to 2013. Most of the contaminated sediment moved to river mouths of Tokyo Bay from Arakawa River. On the other hand, in Edogawa and Sumidagawa River contaminated sediment still remained in the middle region. The supply of contaminated sediment from upper most regions were already limited and most of the contaminated sediment buried in the middle region of 4-18 cm depth from the river bed in those three rivers which was enough deep to prevent further exposure of the contaminated sediment to Tokyo Bay.

6. References:

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