

**Master's Thesis**  
**Supervised by: Assoc. Prof. Dr. Yukio Koibuchi**

**Field Observation of Cesium Radionuclide in Ohori River and Lake  
Teganuma Sediment, Chiba Prefecture, Japan**

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## CHAPTER 1: INTRODUCTION

### 1.1 General Introduction

The Fukushima Nuclear Power Plant (FNPP) accident on March 2011, led to the continuous discharge of radionuclide into the atmosphere and the oceans, in the form of radioactive gases or very fine radioactive particles (aerosols) scattered into the air (IRSN, 2012). These aerosols were mostly produced by the nuclear fission of  $^{235}\text{U}$  and released directly into the atmosphere. The radioactive nuclides particularly the radioactive Cesium-134 ( $^{134}\text{Cs}$ ) and Cesium-137 ( $^{137}\text{Cs}$ ) is of utmost concern because it adversely affects human health through contamination of air, water, soil and food (Morino et al., 2011). The transfer and deposition of radiocesium is an important mechanism to determine the future effects on human health, ecosystem and natural environment and thereby the food chain (Domis, 1997). Vertical soil profile analyses are essential to estimate the radiation dose to people living in and around the area (Chino et al., 2011) as they are able to impart valuable information for the decontamination of radionuclides from the soil, transfer to the crops and migration of the radionuclides from the soil to other systems.

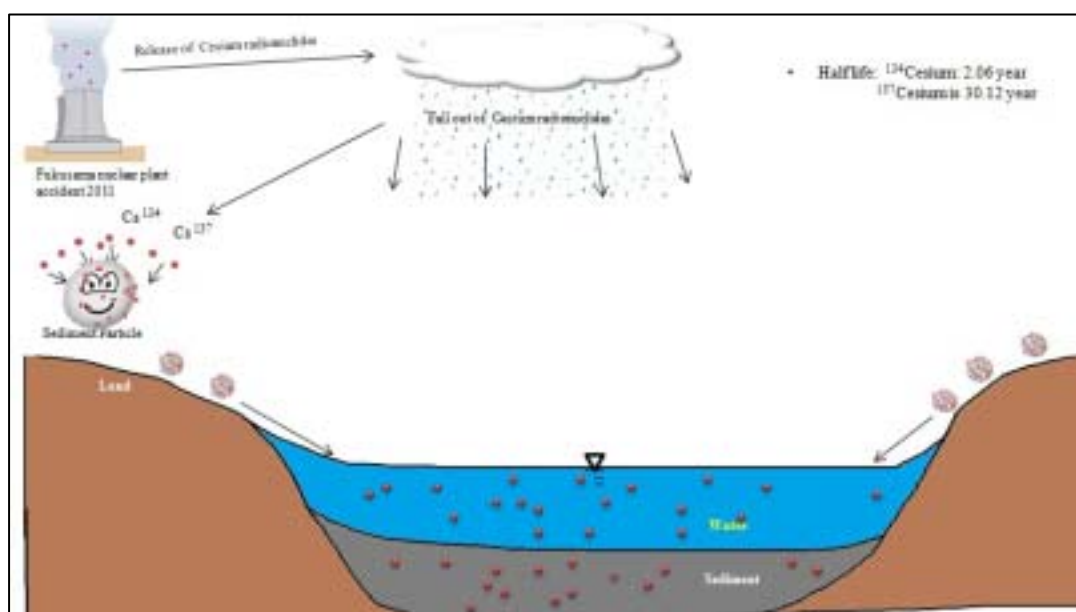


Figure 1.1: Illustration of radiocesium transferred to the Land and River

The radiocesium nuclides are generally attached to small dust particles (aerosols) in the atmosphere and enter the terrestrial ecosystem through rainfall and are deposited on the soil surface. Over longer time periods, after being deposited by precipitation in the form of rain, radiocesium nuclides held in the soil catchment are slowly transferred to river water by erosion of soil particles and (in dissolved phase) by desorption from soil (Figure 1.1).

The accumulation of radiocesium ( $^{134}\text{Cs}$  and  $^{137}\text{Cs}$ ) after the great Tohoku earthquake and Tsunami in March 2011, were monitored and reported by Ministry of Education, Culture, Sports, Science and Technology. As shown in the figure 1.2 (a) and (b), the highest levels of  $^{134}\text{Cs}$  and  $^{137}\text{Cs}$  on the surface of land were found within the 20 km zone and values greater than  $3 \times 10^9 \text{ Bq/m}^2$  and also the highest levels of  $^{134}\text{Cs}$   $14 \times 10^6 \text{ Bq/m}^2$  and  $^{137}\text{Cs}$   $15 \times 10^6 \text{ Bq/m}^2$  lie to the west of the power plant.

The surface area of the contaminated land in Japan compared to the contaminated area around Chernobyl was estimated by IRSN, 2012. The estimated result shows that the overall deposit of  $^{137}\text{Cs}$  is greater than  $6 \times 10^5 \text{ Bq/m}^2$  within an area of  $600 \text{ km}^2$  in Japan, which is 20 times less than the surface area as compared to  $13,000 \text{ km}^2$  around Chernobyl. It clearly explains that the contamination level in Japan was comparatively smaller to that of Chernobyl.

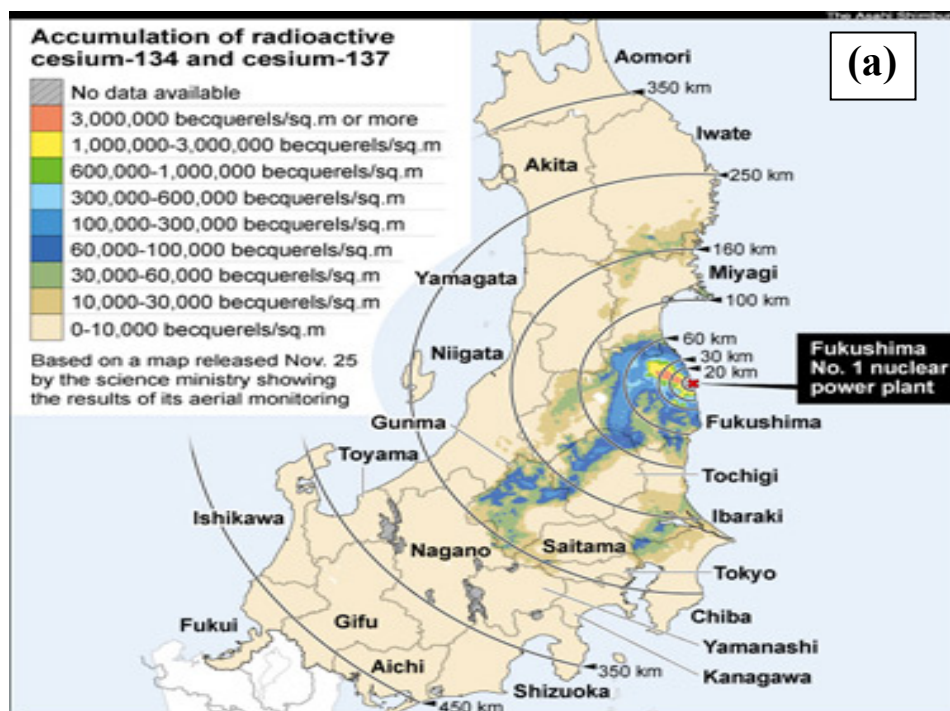


Figure 1.2: (a) Accumulation of radiocesium  $^{134}\text{Cs}$  and  $^{137}\text{Cs}$  the result of aerial monitoring on 25 November 2011 (Asahi Shimbun, Nov. 26, 2011)

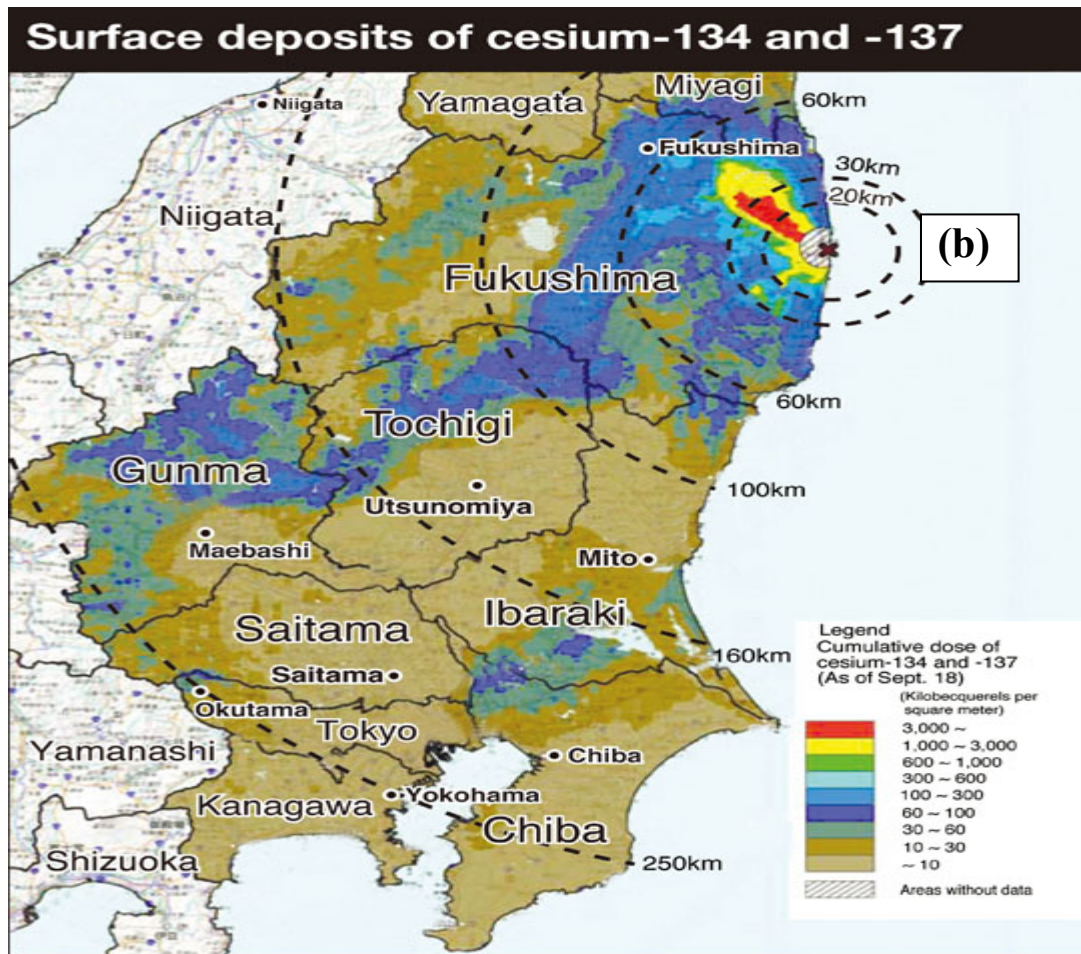
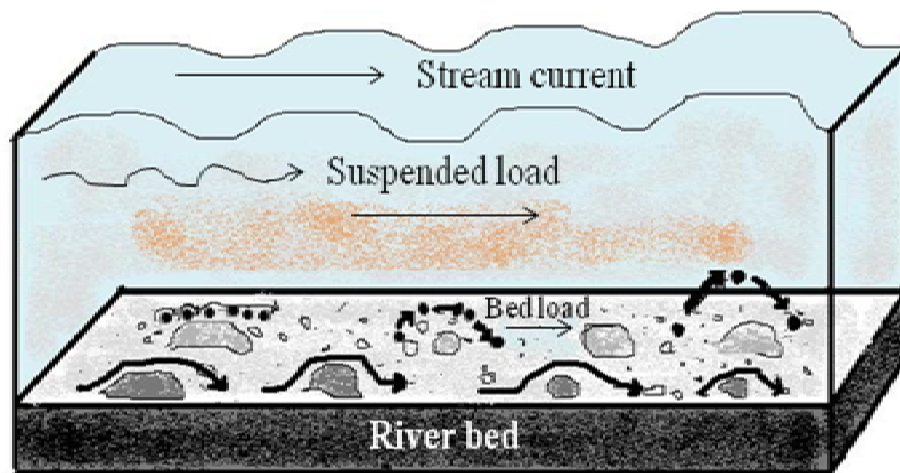


Figure.1. 2: (b) Cumulative deposits of  $^{134}\text{Cs}$  and  $^{137}\text{Cs}$  on surface as on 18 September 2011 (Results by Ministry of Education, Culture, Sports, Science & Technology as published in Japan Times, October 8, 2011)

In the riverine system, radiocesium originating from fallout events in the upstream basin are actively adsorbed by soil particles and can subsequently be mobilized again through erosion events and transported downstream as part of the suspended sediment load (Walling and He, 1993). The suspended material, which is primarily, eroded soil particles carrying  $^{134}\text{Cs}$  and  $^{137}\text{Cs}$  is deposited rapidly during the sediment deposition process. Thus, the sequential buildup of deposited sediment reflects the time distribution pattern of radionuclide fallout. Radionuclide is widely used in soil erosion and sedimentation research due to its high affinity for fine particles, its relatively long half- life, its relative ease of measurement and the well defined temporal pattern of fallout input (Ritchie and Mc Henry, 1990; Walling and Quine, 1993).

Radiocesium nuclide is accumulated in river-bed sediments in the form of sediment load. Sediment load is defined as the sum of suspended load and bed load

(Zhen-Gang Ji, 2008) and is illustrated in Figure 1.3. Following Edward J. Hickin, 1995, (1) Suspended sediment transport refers to the particles or grains of sediment moving along a river within and wholly supported by the flow. The suspended sediment load in the river consisted largely of the finer sediment fractions; fine sand, silt and clay. These suspended sediments (fine sand) tend to have higher concentration and the size and the concentration of the suspended sediment in the water column reduces from the bottom towards the surface water flow. (2) In the form of bed load, the bed material moves by sliding and rolling, where the movement often occurs intermittently in a thin layer of several grain diameters in thickness, on or close in contact with the bed. It is often difficult to distinguish the two modes of sediment transport completely within the same water body.



**Figure1. 3: Sediment load in river bed**

However, bed load transport can be estimated by using radiocesium tracer. This technique can trace the movement of  $^{134}\text{Cs}$  and  $^{137}\text{Cs}$  in the sediment bed by understanding its physical processes (i.e, adsorption in soil particles). This is because the radiocesium isotopes have considerable advantages as water tracers exhibiting effective chemical properties of long residence times. Secondly, they have a ‘decay based internal clock’ (McKinley et al.,1981), where  $^{134}\text{Cs}$  and  $^{137}\text{Cs}$  have decay half-lives of 2.06 and 30.4 years (chk Baxter et al., 1979) regardless of freshwater dilution or cesium removal processes, the  $^{134}\text{Cs}$ : $^{137}\text{Cs}$  ratio of the dissolved radiocesium halves every 2.20 years during water transport.



## 1.2 Rationale of the study

On the basis of the Reports published by the Ministry of Education, Culture, Sports, Science and Technology, the contamination area of  $^{134}\text{Cs}$  and  $^{137}\text{Cs}$  has been considerably high in North-West of Chiba prefecture. High contamination deposits of radiocesium nuclides on land surface was found around Kashiwa city and Abiko city and varies around  $6 \times 10^4 \text{ Bq/m}^2$  even though it is located 195 km away from the FNPP. The environmental radioactivity levels are a growing concern not only for public health and safety but also with respect to the ecosystem contamination. Since  $^{137}\text{Cs}$  has a long half-life of 30.04 year and it is relatively easy to detect, this study emphasizes the concentration distribution of  $^{134}\text{Cs}$  of  $^{137}\text{Cs}$  in the Ohori River and Lake Teganuma (Figure 1.4). Moreover over the next few decades,  $^{137}\text{Cs}$  will continue to be the most relevant radionuclide as far as exposure to radiation is concerned (c.f Figure 1.5).

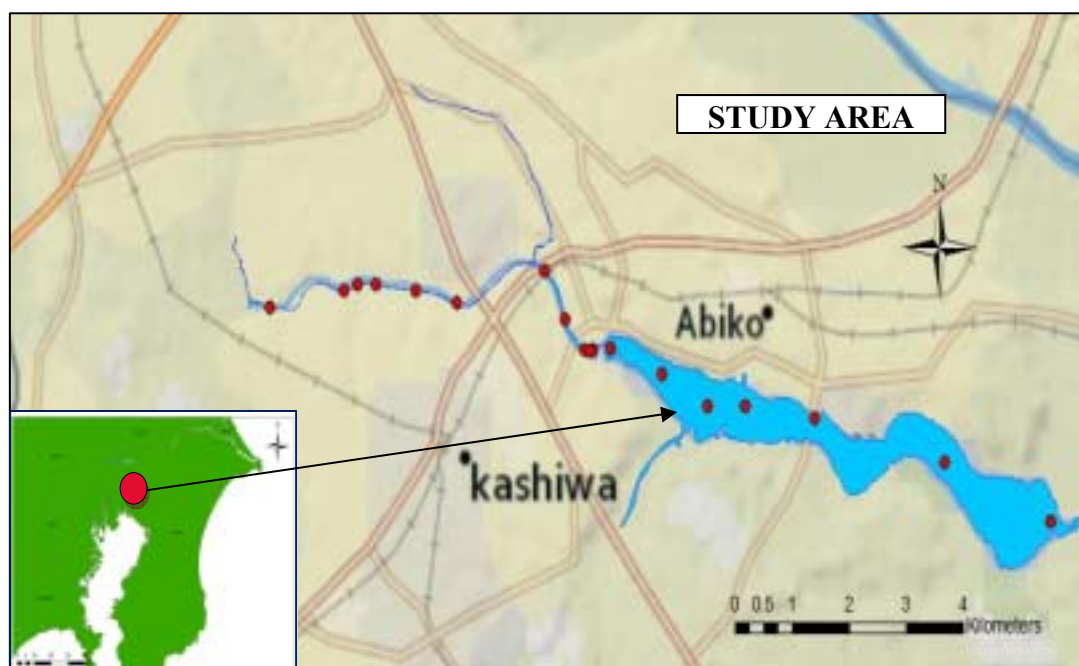


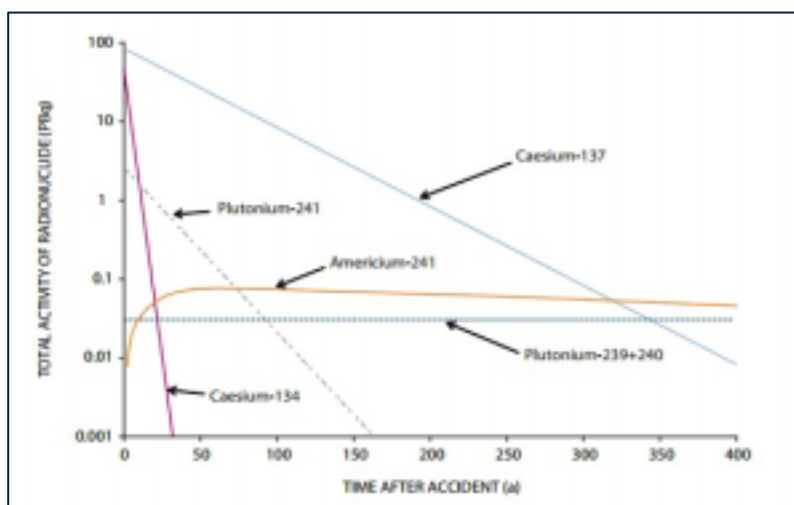
Figure 1.4: Location of Ohori River & Lake Teganuma

The Ohori river basin is located in the northwestern part of the Shimousa Upland, in the eastern part of the Tokyo Metropolitan Area. The landform consists of an upland surface at altitudes of 15-30 m and alluvial lowland 2-9 m. There are two major rivers in the basin, Ohori and Jigane-hori Rivers. The 6 km long Jigane-hori River begins at two natural ponds near Kashiwanoha Park and drains into the Ohori River near Yabatsuka Bridge. The two rivers have many tributaries which dissect the land surface into many

smaller basins. The total area of the drainage basin is 31 km<sup>2</sup> (Mezbaul Bahar, 2008). The Ohori river begins at Aota-shiden, Kashiwa city, Chiba prefecture, passing through Nagarayama City and Kashiwa city, and finally drains into Lake Teganuma.

While, Lake Teganuma, located in Abiko city in the northwest of Chiba prefecture, occupies a narrow, east to west stretch borders the north of Tonegawa River. Lake Teganuma is known to have a record of being the most polluted lake in Japan for 27 consecutive years starting from 1974, when the then Environment Agency (now the Ministry of Environment) began nationwide surveys of lake and marsh water quality (JFS Newsletter No.33, May 2005). Lake Teganuma is a polymictic shallow lake with an average depth of 0.86 m. A polymictic lake is holomictic in the sense that the lake is very shallow so that it is homogeneous thermally or there is little or negligible thermal stratification. The Lake has a length of about 7 km and surface area of 4.28 km<sup>2</sup> with 17 km shoreline. The water source of the lake originates from a catchment area of about 162.88 km<sup>2</sup> supplied by Ohori and Otsu rivers and two other canals (Deepak, 2007).

The field observation was started from July 2012 to May 2013. Core sediment samples and surface sediment samples were collected from both the river and the lake starting from July 2012. Soil samples were also collected in June 2013 from the Ohori river basin. Radionuclide content and the particles size from the land surface soil profiles and sediment core samples from the river and lake were measured. The concentration and depth of <sup>134</sup>Cs and <sup>137</sup>Cs in sediment profiles can be used to calculate the total sediment load (tonnes) and total amount of radiocesium accumulated in Ohori River and Teganuma Lake after March 2011.



**Figure 1.5: Residence time of different radionuclide (after UNSCEAR Report Vol. II)**

### 1.3 Objectives:

The overall goal of this study is to estimate the total mass of sediment (tonnes) and total amount of radiocesium accumulated in Ohori River and Teganuma Lake after March 2011 by using radiocesium isotopes as tracers.

The specific objectives of this study are as follows:

- To measure the distribution of radiocesium in the core samples.
- To measure and compare the radiocesium concentration for each of the different particle sizes (45µm, 75µm, 106µm & 250µm c.f. Figure 2.6) from the land surface soil profiles and sediment cores from Ohori river and Lake Teganuma.
- To estimate the total mass of sediment contaminated with radiocesium in the Ohori river and Lake Teganuma
- To estimate the of total amount of radiocesium concentration in the Ohori river and Lake Teganuma

### 1.4 Thesis Outline

All chapters in this thesis are self contained with figures, tables and references. The thesis layout is as follows:

**Chapter 1** is the *General Introduction* to this research with a *Rationale of the study* which lays emphasis to the purpose of this study with respect to previous literature reviews. This is followed by the specific *Objectives* and is followed by,

**Chapter 2** which explains in detail the location of the *Sampling sites* selected for the sediment core sampling along the Ohori river and Lake Teganuma. It also details the land surface soil profile sites selected in the vicinity of Kashiwa-no-ha. Extensive *Field observations* that is the basis of this research has also been illustrated with the help of photographs. *Laboratory analysis* finds mention in the latter half in much detail.

**Chapter 3 & Chapter 4** are the core chapters that explain the *Results & Discussions of experiment analysis*.

Finally, **Chapter 5** consists of *Conclusions and recommendations* of this study

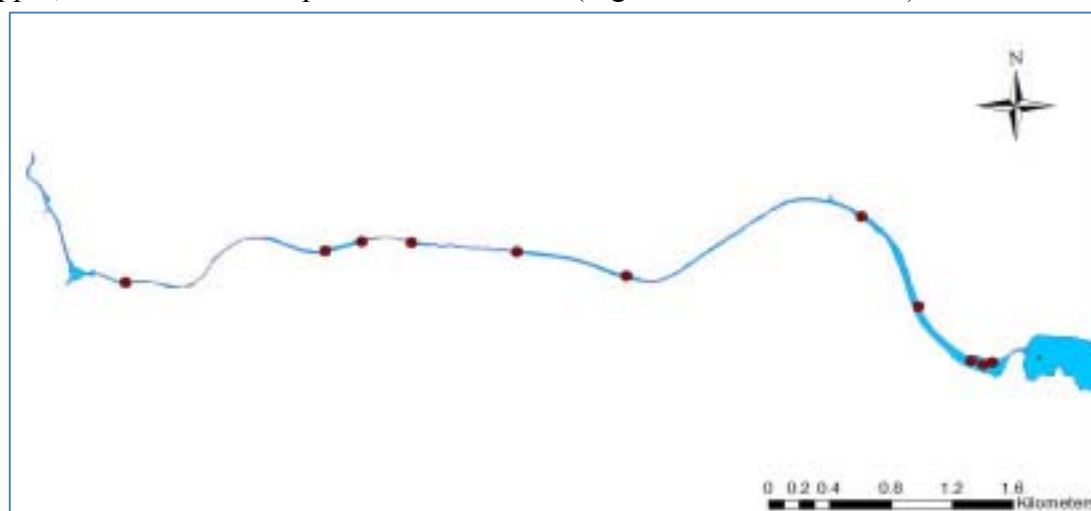
## CHAPTER 2: MATERIAL AND METHODOLOGY

This chapter provides the framework of the methodology in four sections. The first section outlines the selection of sampling site and study area. The second section describes the field observations for each of the sampling sites and the third section outlines the laboratory analysis of soil and sediment samples and lastly, the fourth section provides all the calculations for determining the total sediment load and total amount of radiocesium in the Ohori River and Lake Teganuma (from July to December 2012- February to May 2013).

### 2.1 Sampling site

#### Ohori River

The Ohori River which flows to Lake Teganuma was selected as the sampling site. The Ohori River starts at Aota-Shinden, Kashiwa City, Chiba Prefecture, and passing through Nagareyama and Kashiwa City, and then drains into the Lake Teganuma. The catchment area is approximately 31 km<sup>2</sup> and the the length is 12.9 km. Samples were collected from eleven (11) stations along the Ohori River, starting from the upper stream down to the mouth of Lake Teganuma. Stations were divided into the upper, middle and lower portions of the river. (Figure 2.1 and Table 2.1)



**Figure 2.1 Location of Sampling Points in Ohori River**



**Table 2.1: Geographic locations of sampling stations in Ohori River**

Observation point	Latitude	Longitude	Length from One station to another(m)
St.1	35°52'18.19"N	139°56'21.56"E	1.474
St.2	35°52'24.07"N	139°57'4.00"E	
St.3	35°52'25.95"N	139°57'11.68"E	200
St.4	35°52'25.74"N	139°57'22.23"E	290
St.5	35°52'23.93"N	139°57'44.56"E	550
St.6	35°52'19.41"N	139°58'7.82"E	620
St.7	35°52'30.58"N	139°58'57.67"E	1.755
St.8	35°52'13.70"N	139°59'9.70"E	789
St.9	35°52'3.50"N	139°59'20.80"E	537
St.10	35°52'2.90"N	139°59'23.50"E	87
St.11	35°52'3.20"N	139°59'25.30"E	267

*Note:* Name of each stations are Stn1: Shinkomagi bridge, Stn2: Shinbashi bridge, Stn3: Shintsutsumi bridge, Stn5: Takada bridge, Stn6: Showa bridge, Stn7: Kitakashiwa bridge , Stn8: downstream point1, Stn9: downstream point 2, Stn10: downstream point 3, Stn11: downstream point 4.

### 2.1.2 Ohori Basin

Ohori river basin is located in the northwestern part of the Shimousa Upland, eastern part of Tokyo Metropolitan Area. The landforms consist of upland surface at altitudes of 15-30m and alluvial lowland at 2-9 m. There are two major rivers in the basin, Ohori and Jigane-hori. The soil sampling points are distributed in twenty station around Kashiwa-no-ha area and the samples were collected in June, 2013.

### 2.1.3 Lake Teganuma

Lake Teganuma is a landmark found within both Kashiwa City and Abiko City in the northern part of Chiba Prefecture. It is a long lake with a length of about 7 km, and a shoreline of 17 km. Samples were collected from seven (7) sampling stations which are distributed from the upstream to downstream portion of the river.(Figure 2.2 and Table 2.2).



**Figure 2.2 Location of sampling points in Lake Teganuma**

According to the information from Deepak, 2007, the major source of water inflows that discharge to Lake Teganuma come from: Ohori River, Otsu River , Somei-iriotoshi River, Kita Chiba No.2 Pumping station, ground water infiltration, non-point sources and small adjoining canals, and precipitation. The major outflows of the lake include: Tega River, Izumi Irrigation Pumping Station, Takano Yama irrigation

pumping station and evaporation. The two major irrigation pumping stations pump out water from Lake Teganuma into paddy fields during April to August.

**Table 2.2 Geographic Locations of sampling points in Lake Teganuma**

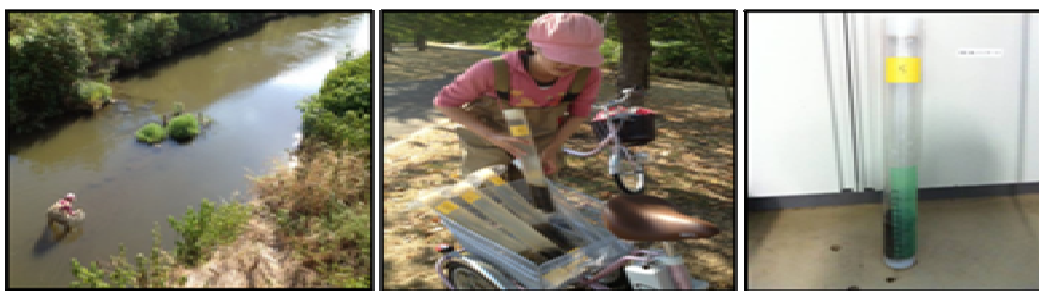
<b>Observation point</b>	<b>Latitude</b>	<b>Longitude</b>	<b>Length from One station to another(m)</b>
St.1	35°52'5.22"N	139°59'35.52"E	963
St.2	35°51'55.08"N	140° 0'5.22"E	
St.3	35°51'43.80"N	140° 0'30.90"E	908
			664
St.4	35°51'43.92"N	140° 0'52.32"E	1.239
St.5	35°51'39.48"N	140° 1'31.68"E	
St.6	35°51'24.72"N	140° 2'46.26"E	5.506
			2.010
St.7	35°51'4.44"N	140° 3'44.10"E	

## **2.2 Field observation**

As shown in Table 2.3, sediment core samples (with internal diameter of 5.4 cm) collection started from the month of July 2012 and thereafter, sediment core samples continued to be collected every month from July until December 2012. In July, 2012 sediment core sample collection was begun from the middle part of Ohori River (from Station 2 to Station 6). In August and September, core samples were collected at one more station in the upper part of river (Station 1), so this time, data was collected from all six stations (Station 1 to Station 6). In October, surface sediments were collected at all 6 stations (3 cm of surface sediment) and core samples were collected at 2 stations (Station 5 and Station 6). In addition, sediment core samples were collected from seven stations in Teganuma Lake (using a core sampler internal diameter of 4 cm) on 17 October 2012. Sample collection in the lower part of the river was started in November and December (Station 7 to Station 11).

Thus, collected samples were carried back to the laboratory for further analysis. But during transfer, sample care was taken for the core samples, not to fall down or mix with the sediments inside the core sampler. As Figure 3.2.1 and 3.2.2 shows the sample collection on field by using core sampler at the Ohori River and Teganuma Lake.

In 2013, sediment core samples were collected again and starting from February from surface 3 cm in eleven stations of Ohori River. In March core samples were collected from 6 Stations at Ohori River (Station 1, Station 3, Station 5, Station 9, Station 10 and Station 11) and seven Stations at Teganuma Lake. In the month of May the last samples were collected at Teganuma Lake and were further analysis of radiocesium was continued at the Laboratory.



## **Ohori river**

**Figure 2.3 Sediment core sampling in Ohori River**



## **Teganuma Lake**

**Figure 2.4 Sediment core sampling in Lake Teganuma**

**Table 2.3 of Sampling Observation in Ohori river**

<b>Date</b>	<b>point</b>	<b>type</b>	<b>Measured</b>
16-Jul-12	St2&st6	Core samples	Cs134&137
31-Aug-12	St2,st3,st4,st5,st6	Core samples	Cs134&137
26-Sep-12	St1-st6	Core samples	Cs134&137 and paticles size
30-Oct-12	St1-st6	Surface samples	Cs134&137
		Core samples(St5&6)	Cs134&137and paticles size
30-Nov-12	St7,st8,st9,st11	Core samples	Cs134&137
28-Dec-12	st9,st10,st11	Core samples	Cs134&137
20-Feb-13	st1-st11	surface samples	Cs134&137
		Core samples (st2,st3,st5)	
28-Mar-13	st2,st3,st5	Core samples (st2,st3,st5)	Cs134&137
29-Mar-13	st9,st10,st11	Core samples	

**Table 2. 4 Schedule for sampling observation in Lake Teganuma**

Date	Point	Type	Measured
17-Oct-12	st1-st7	Core samples	Cs134&137 and particles size
29-Mar-13	st1-st7	Core samples	Cs134&137 and particles size
25-May-13	st1-st7	Core samples	Cs134&137 and particles size

The multi sampler is using sample to a depth of 5 m in the lake. The material are multi sampler with cutting heads, sampling tube, acrylic diameter 40×1000 mm , 5m rope, handle with detachable grip 60 cm, extension rod 100 cm, stainless ball and rubber piston. sediment core sampling shown in figure 2.4.

## **2.4 Laboratory analysis**

Sediment core samples were carried to laboratory in vertical position without mixing or shaking. Core samples were divided into layers of 2 cm heights ( Ohori River samples) and 3 cm heights ( Teganuma samples) the samples were kept in Ziploc pouches and transferred to refrigerator before analysis in order to, measure the radiocesium concentration and particlesize classification. The measurement and analysis process will be described in each section.

### **2.4.1 Analysis of Radiocesium ( $\text{Cs}^{134}$ and $\text{Cs}^{137}$ )**

Sediment samples were divided in two sub samples (wet samples for particle size analysis and dry samples for measurement of radiocesium concentration ). Dry Sediment samples in 105°C within 12 hour or 24 hour depend on samples condition and after dry put in Ziploc. The date, place, layer and name of person who collected were

noted in Ziploc of each samples then the weight before measurement of the radiocesium concentration was noted.

$^{134}\text{Cesium}$  and  $^{137}\text{Cesium}$  were measured by detecting  $\gamma$ -rays of 662keV, and the instruments used were a  $\gamma$ -rays- detecting device and a spectrum navigator, made by ORTAC,USA (GMX29 HP-Ge) and Seiko EG and G Co. respectively . Liquid Nitrogen was filled three times per week to keep the cool environment during measurement.

Gamma-ray spectrometry can identify the presence of man-made radiocesium for radioactive fallout during the nuclear test worldwide before 1963, Chernobyl accident in 1986 and Fukushi Daichi power plant accident in 2011. In the year 1957, the International Atomic Energy Agency (IAEA), and inter governmental forum for scientific and technical cooperation in the peaceful used of the nuclear technology worldwide was established (Deepak, 2007).

#### **2.4.2 Analysis of sediment size**

The median diameter in each sediment column of core samples was measured using a laser diffraction particle size analyzer (SALD-3000S) produced by Shimadzu Co. with the compatible software (Wing SALD -3000S). Laser diffraction and laser scattering were principles of measurement.

Sediment (wet) samples were prepared and small amount of sample was input into the sample bath and stirred. The particle cause diffraction of a laser beam directed through the carrier fluid (water). The angle of scattering is inversely proportional to the particle size, while intensity of scattering is proportion to the number of particles. A cleaned, disaggregated sample was dispersed in carrier clean water and passed thought the inlet flow.

Using the laser diffraction particle size analyzer, particle size distribution was calculated from the light intensity distribution data of the scattered light detected by the photo sensor. The measuring unit uses a total of 79 photo sensor elements to detect the scattered light and it takes about 0.08 seconds to detect one data of signal from all 79 sensors. One data for measurement is obtained by averaging several signals for each sensor element.

When particle size distribution calculations were completed the result was displayed on the console screen as showing by graph and table (Figure 3.4) in PC then save data in a file. The a laser diffraction particle size analyzer can measure the particle size rang 2 mm and do not measure any samples which contain large amount of particles greater than 2 mm. the one more important part is keep it clean any time after finish measurement by clean water .

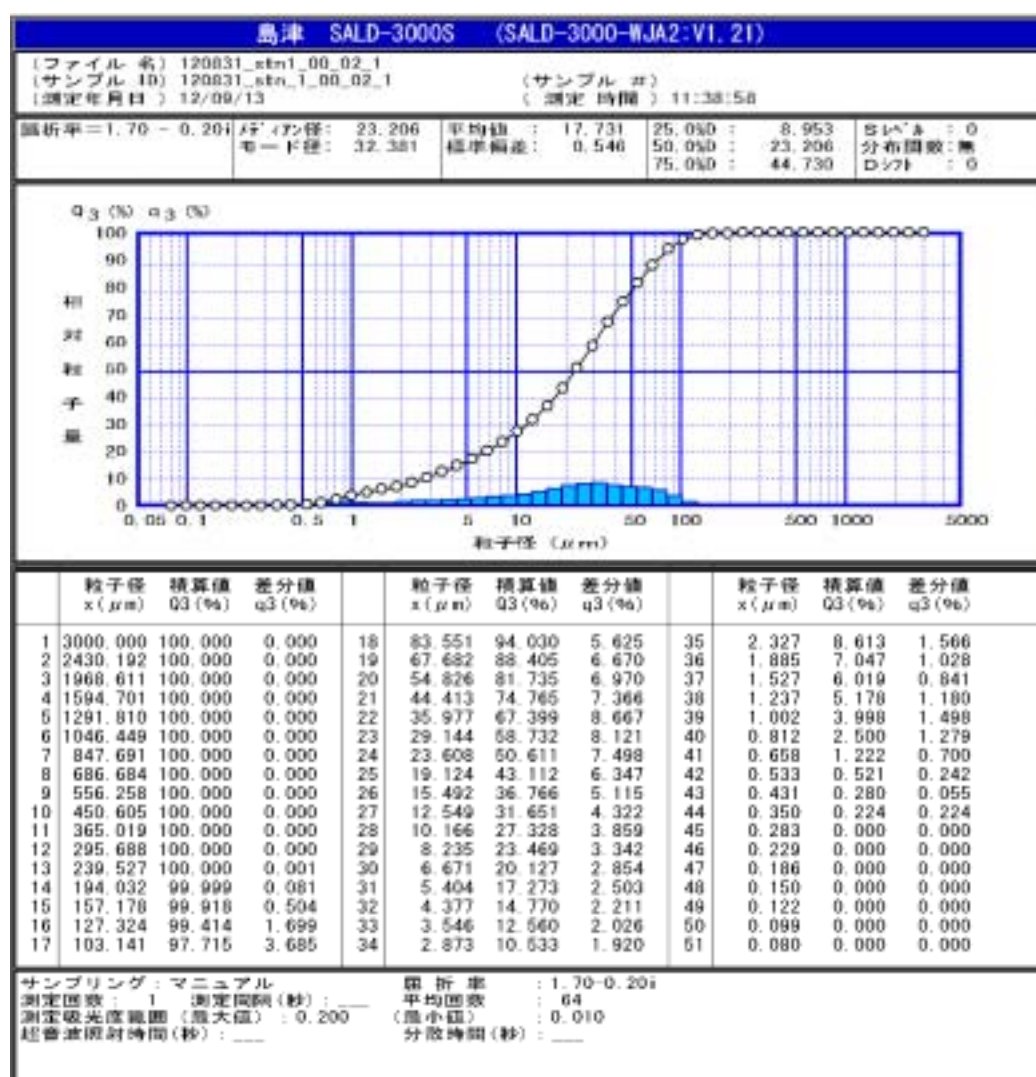


Figure 2.5 Particle size distribution, data graph and table



The mean value deviation is defined as:

$$\text{Mean Value} = 10^{\mu}$$

$$\mu = \frac{1}{100} \sum_{j=1}^n q_j \left( \frac{\log_{10} X_j + \log_{10} X_{j+1}}{2} \right)$$

Where,

$X_j$  = particle size ,  $q_j$  = differential %

The size of Sediment particle diameter is classified and there are many several of classifications System, the standard size classes of particles were classified on basis of Wentworth Grade Scales. The grain size scale commonly used the six Wentworth size classes Micrometers ( $\mu\text{m}$ ). The rang from mud (particles  $< 62.5\mu\text{m}$ ), Very fine sand (particles  $62.5\text{-}130 \mu\text{m}$ ) , Fine sand (particles  $130\text{-}250 \mu\text{m}$ ), Medium sand (particles  $250\text{-}500 \mu\text{m}$ ) and Coarse sand (particles  $500\text{-}1000 \mu\text{m}$ ).

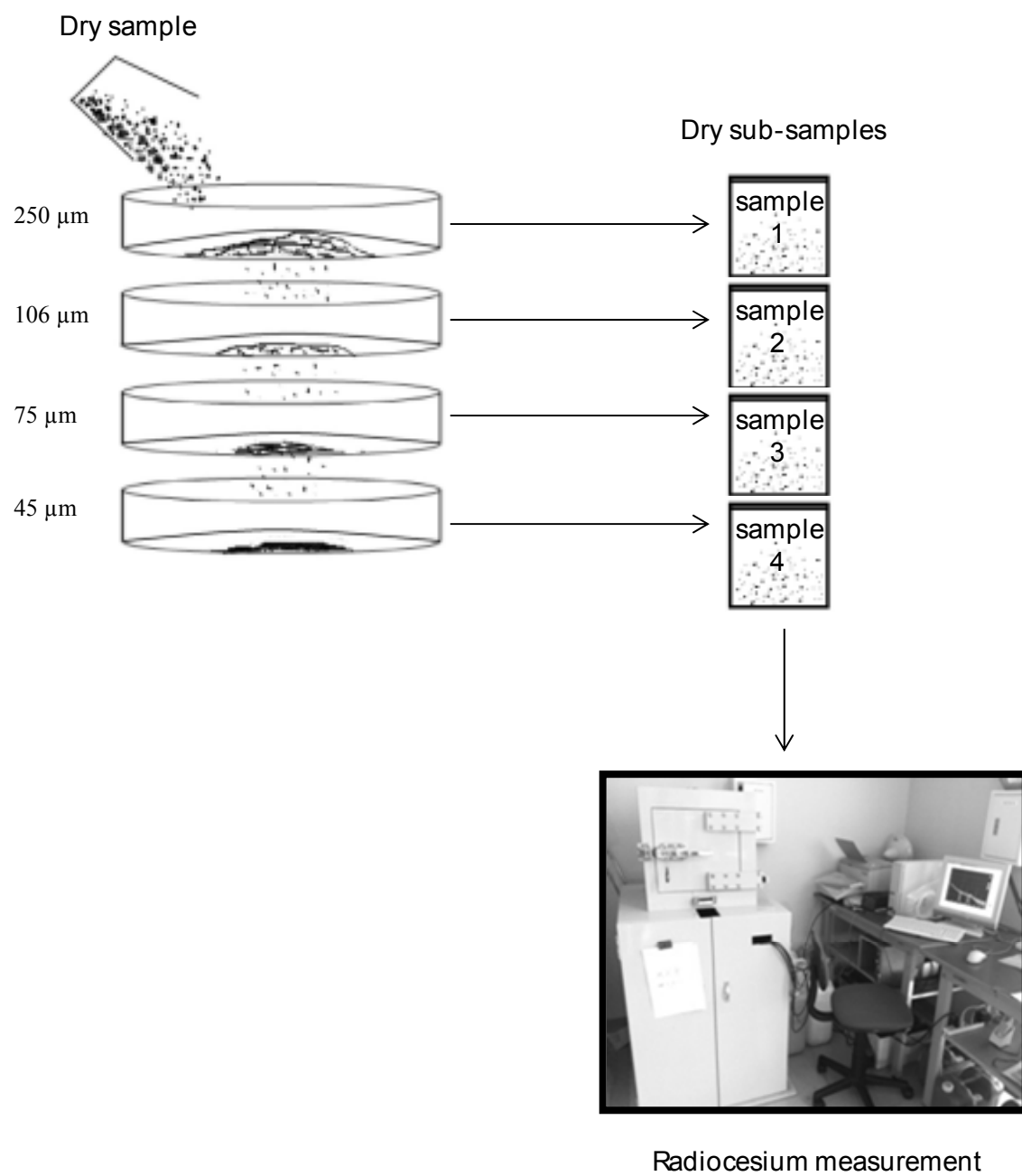
The table in below description on sediment classification and compares the three most frequently encountered in European habitat mapping studies, there are Folk, Wentworth and MNCR classifications.

**Table 2.5 Sediment classification systems: Folk, Wentworth and MNCR**

Sediment Classification Systems: MNCR, Wentworth and Folk						
phi value	mm	Size Class				
		MNCR		Wentworth		Folk
-8	256	Boulder		Boulder		Gravel
		Cobble		Cobble		
-6	64	Pebble		Pebble		
-4	16	Gravel				
-2	4	Coarse		Granule		
-1	2			Very coarse		
-0.5	1.41					
0	1	Coarse				
0.5	0.71			Medium		
1	0.5					
1.5	0.35	Medium				
2	0.25			Fine		
2.5	0.17					
3	0.125	Very Fine				
3.5	0.088			Mud		
4	0.0625					
		Silt				Mud

### **2.4.3 Sieve Analysis.**

To measure radiocesium for each soil and sediment samples, 2 samples were selected in sediment (surface sediment in lower part of river) and 2 samples in the land soil which is highest concentration to measure the concentration of radiocesium in each particle size. After drying samples 24 hour in 105°C, were measured the weight in each sample before sieving and using standard sieve in different diameter (250 µm, 106 µm, 75 µm and 45 µm), the particle remain in each layer of sieve will input into Ziploc and measured the radiocesium by using Gamma-ray spectrometry to find out the dependence of radiocesium concentration in each particle size show in the figure 2.5.



**Figure 2.6 Sieve Analysis and radiocesium measurement process**

## **2.5 Calculation of the total mass of sediment and amount of radiocesium in Ohori river and Lake Teganuma**

### **Total Volume of sediment (m<sup>3</sup>) :**

The total volume of sediment contaminated with radiocesium can be estimated as the sum over the depth profile of radiocesium times area of each region, calculated by:

$$V = \sum_{i=1}^n (A_i \cdot D_i) \quad (2.5.1)$$

where,

V=Total Volume (m<sup>3</sup>), A<sub>i</sub>= surface area of each point (m<sup>2</sup>) and D<sub>i</sub>= depth of radiocesium (m)

The surface area in each sampling point was obtained by using Arc GIS 9.3. The shapefile for Ohori River and Lake Teganuma was created and the area was calculated using the “calculate the geometry” option from the selected feature file.

### **Total mass of sediment (Ton) :**

The total mass of the sediment expressed in tons was derived by getting the weight of 100 mL volume sample of sediment. After getting the weight in grams, it is then converted to cubic meter unit and tons.

$$100\text{ml} = 156.231 \text{ g}$$

$$1\text{m}^3 = 1.56 \text{ Ton}$$

The total mass of sediment can be calculated by :

$$M = (V_i \times 1.6) \times 1000 \quad (2.5.2)$$

where,

$V_i$  = volume of each point ( $m^3$ ) convert to Ton by multiply of value 1.6 and convert to Kg by multiply of value 1000 .

**Total amount of radiocesium (Bq) :**

$$\text{Total amount of radiocesium (Bq)} = \sum_{i=1}^n (M/L.C_i) \quad (2.5.3)$$

where,

$M$ = total mass of sediment (Kg),  $L$ = layer number of core sample,  
 $C_i$ = Concentration of  $Cs^{134}+Cs^{137}$  (Bq/kg).

## CHAPTER 3: RESULTS

### 3.1 Radiocesium ( $^{134}\text{Cs}$ and $^{137}\text{Cs}$ ) concentration analysis of Ohori River in 2012

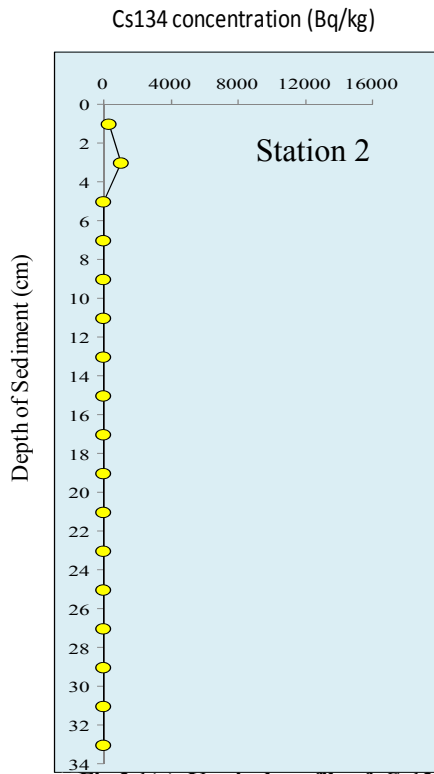
#### 3.1.1 Vertical distribution of $^{134}\text{Cs}$ and $^{137}\text{Cs}$ in core samples upper part of river

Vertical profiles at 6 stations in upper part of river as show in below. Data was started collect core samples on 16 July 2012 (Samples site in Station 2 and Station 6) in middle part of river. Figure 3.1(a) and 3.1(b) shown that in station 2 the concentration of  $^{134}\text{Cs}$  in core sample were found in value  $3.25 \times 10^2$  Bq/kg (0-2 cm) and  $1.05 \times 10^3$  Bq/kg (2-4 cm) ,  $^{137}\text{Cs}$  as value  $6.63 \times 10^2$  Bq/kg (0-2 cm) and  $1.99 \times 10^3$  Bq/kg (2-4 cm) in core depth layer from 0-4 cm , respectively. We found that in the depth 4 cm the concentration of cesium were higher than surface in this time.

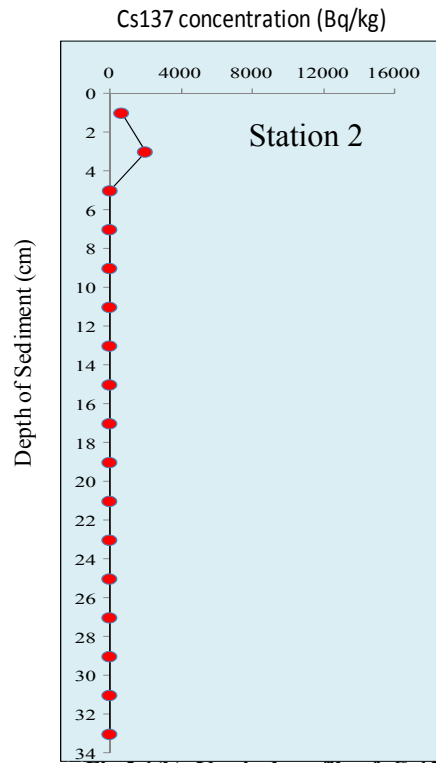
Figure 3.2(a) and 3.2(b) shown that in station 6 the concentration of  $^{134}\text{Cs}$  in core sample were found in depth 0-2 cm with value  $4.30 \times 10^2$  Bq/kg and in the depth 2-4 cm with value 13.78Bq/kg , for  $^{137}\text{Cs}$  were found as value  $8.12 \times 10^2$  Bq/kg and 18.73Bq/kg in core depth from 0-4 cm , respectively. In this sample site were shown that the concentration were high in the surface 0-2 cm and decreased in lower layer gradually.

As the first results of field observation on July 2012 showed that in station 2 and station 6 located in the middle part of river shown the vertical profile of  $^{134}\text{Cs}$  and  $^{137}\text{Cs}$ , which clearly indicates that  $^{134}\text{Cs}$  and  $^{137}\text{Cs}$  has started to deposited in the sediment depth 4 cm in this samples site.

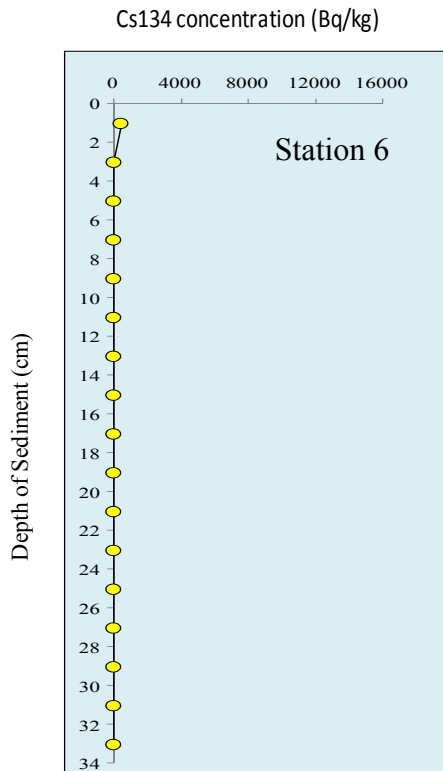
**Figure 3.1-3.2 JULY 2012: Vertical distribution of  $^{134}\text{Cs}$  and  $^{137}\text{Cs}$  in core samples upper part of river**



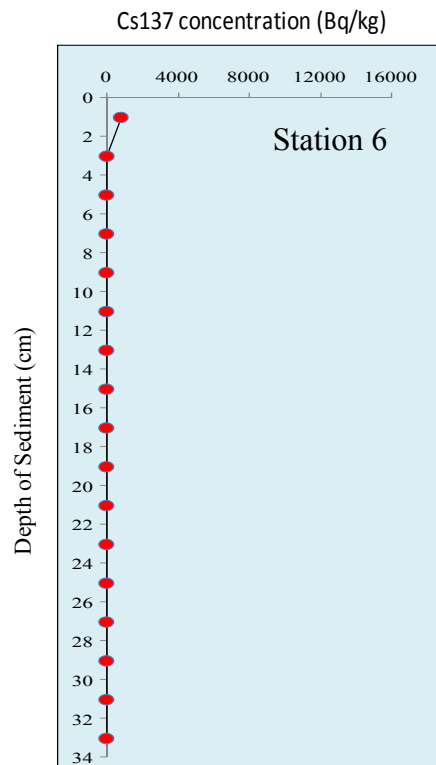
**Fig.3.1(a). Vertical profile of  $^{134}\text{Cs}$  distribution in station 2**



**Fig.3.1(b). Vertical profile of  $^{137}\text{Cs}$  distribution in station 2**



**Fig.3.2(a). Vertical profile of  $^{134}\text{Cs}$  distribution in station 6**



**Fig.3.2(b). Vertical profile of  $^{137}\text{Cs}$  distribution in station 6**

To emphasize the distribution of radiocesium in middle of river, On 31th August samples was collected in 5 stations , between Station 2 and Station 6 were include 3 more station as station 2,3,4,5 and station 6, respectively.

As the result shown that concentration were high in station 4 and station 5 and cesium deposited in the depth 14 cm.

In figure 3.3(a), 3.3(b),  $^{134}\text{Cs}$  and  $^{137}\text{Cs}$  concentration in station 2 the depth of cesium was 0 to 6cm with value from bottom to surface ranging from 63.57 Bq/kg to  $5.98 \times 10^2$  Bq/kg of  $^{134}\text{Cs}$  and the value of  $^{137}\text{Cs}$  ranging from  $1.43 \times 10^2$  Bq/kg to  $1.21 \times 10^3$  Bq/kg, respectively. high concentration was found in surface 0-2cm.

In figure 3.4(a), 3.4(b),  $^{134}\text{Cs}$  and  $^{137}\text{Cs}$  concentration in station 3 the depth of cesium was 0 to 6cm with value from bottom to surface ranging from 21.51 Bq/kg to  $8.97 \times 10^2$  Bq/kg of  $^{134}\text{Cs}$  and the value of  $^{137}\text{Cs}$  ranging from 58.47 Bq/kg to  $1.77 \times 10^3$  Bq/kg, respectively. high concentration was found in surface 0-2cm .

In figure 3.5(a), 3.5(b),  $^{134}\text{Cs}$  and  $^{137}\text{Cs}$  concentration in station 4 the depth of cesium was 0 to 14cm with value from bottom to surface ranging from 25.96 Bq/kg to  $1.40 \times 10^3$  Bq/kg of  $^{134}\text{Cs}$  and the value of  $^{137}\text{Cs}$  ranging from 32.28 Bq/kg to  $2.71 \times 10^3$  Bq/kg, respectively. high concentration also found in surface 0-2cm .

In figure 3.6(a), 3.6(b),  $^{134}\text{Cs}$  and  $^{137}\text{Cs}$  concentration in station 5 the depth of cesium was 0 to 14 cm and 2 peaks were found in the depth 4-6 cm and 10-12 cm with value  $2.44 \times 10^3$  Bq/kg and  $1.99 \times 10^3$  Bq/kg of  $^{134}\text{Cs}$  and the value of  $^{137}\text{Cs}$  were  $5.13 \times 10^3$  Bq/kg and  $4.07 \times 10^3$  Bq/kg, respectively.

In figure 3.7(a), 3.7(b),  $^{134}\text{Cs}$  and  $^{137}\text{Cs}$  concentration in station 6 were found only in surface with the depth 0-2cm with the value of  $^{134}\text{Cs}$  and  $^{137}\text{Cs}$  were 36.87 Bq/kg and 75.16 Bq/kg, respectively.



**Figure 3.3-3.4 AUGUST 2012: Vertical distribution of  $^{134}\text{Cs}$  and  $^{137}\text{Cs}$  in core samples**

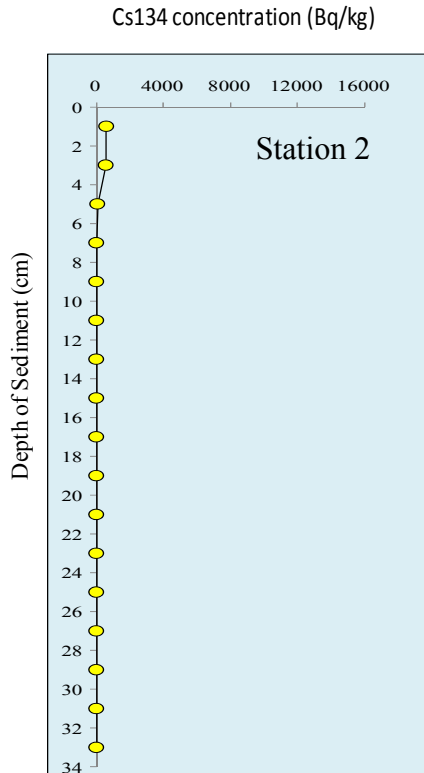


Fig.3.3(a). Vertical profile of  $^{134}\text{Cs}$  distribution in station 2

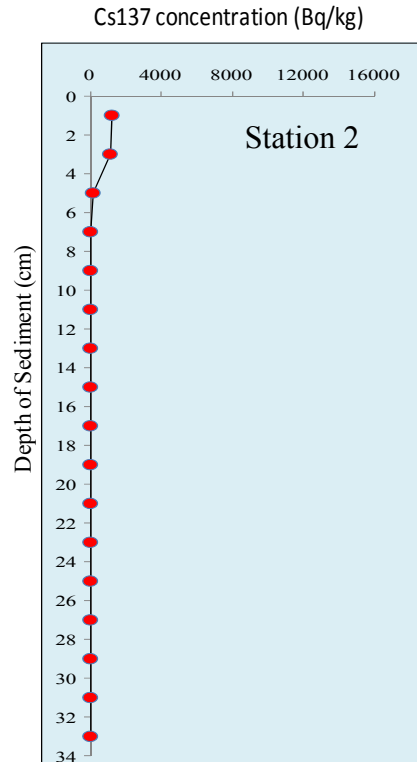


Fig.3.3(b). Vertical profile of  $^{134}\text{Cs}$  distribution in station 2

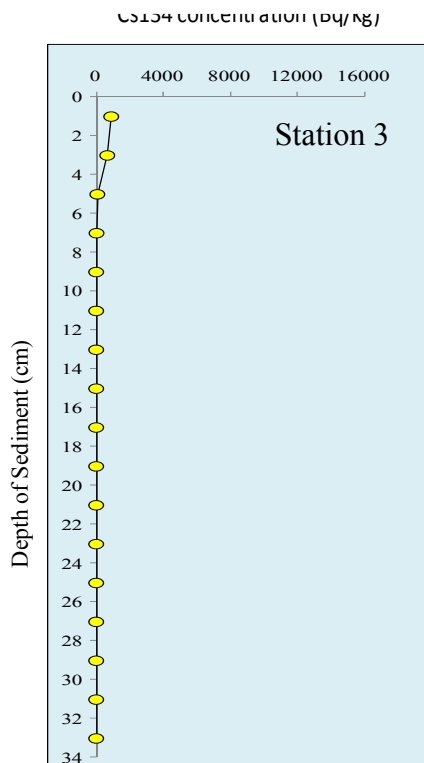


Fig.3.4(a). Vertical profile of  $^{134}\text{Cs}$  distribution in station 3

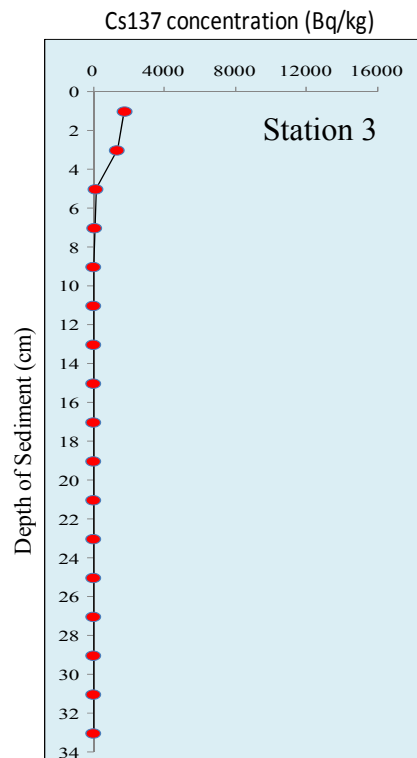


Fig.3.4(b). Vertical profile of  $^{137}\text{Cs}$  distribution in station 3

**Figure3.5-3.6 AUGUST 2012: Vertical distribution of  $^{134}\text{Cs}$  and  $^{137}\text{Cs}$  in core samples**

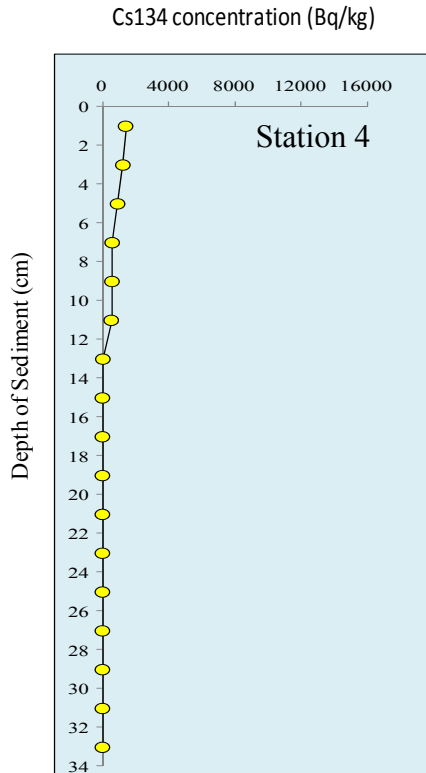


Fig.3.5(a). Vertical profile of  $^{134}\text{Cs}$  distribution in station 4

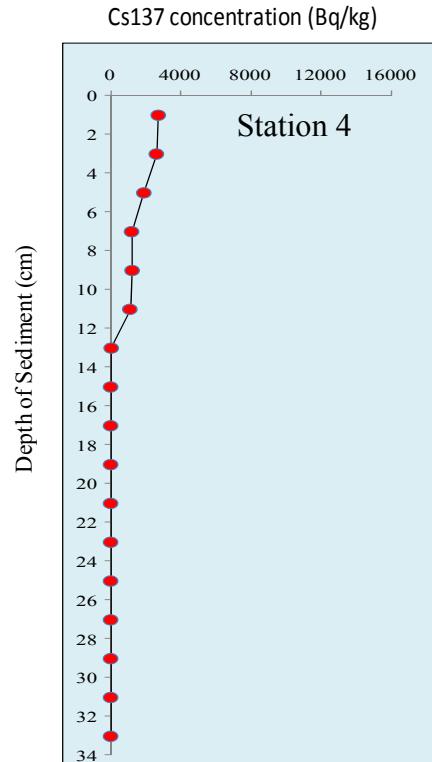


Fig.3.5(b). Vertical profile of  $^{134}\text{Cs}$  distribution in station 4

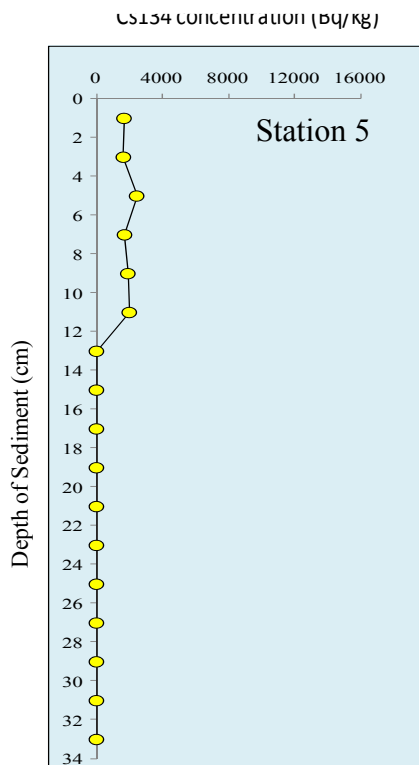


Fig.3.6(a). Vertical profile of  $^{134}\text{Cs}$  distribution in station 5

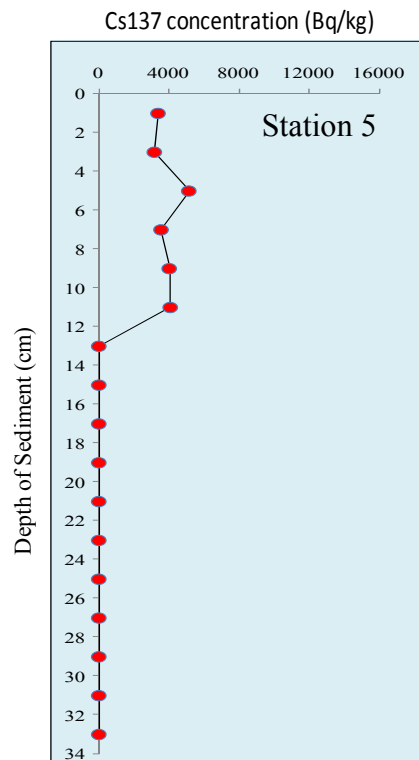


Fig.3.6(b). Vertical profile of  $^{134}\text{Cs}$  distribution in station 5

**Figure 3.7-3.8 AUGUST 2012: Vertical distribution of  $^{134}\text{Cs}$  and  $^{137}\text{Cs}$  in core samples**

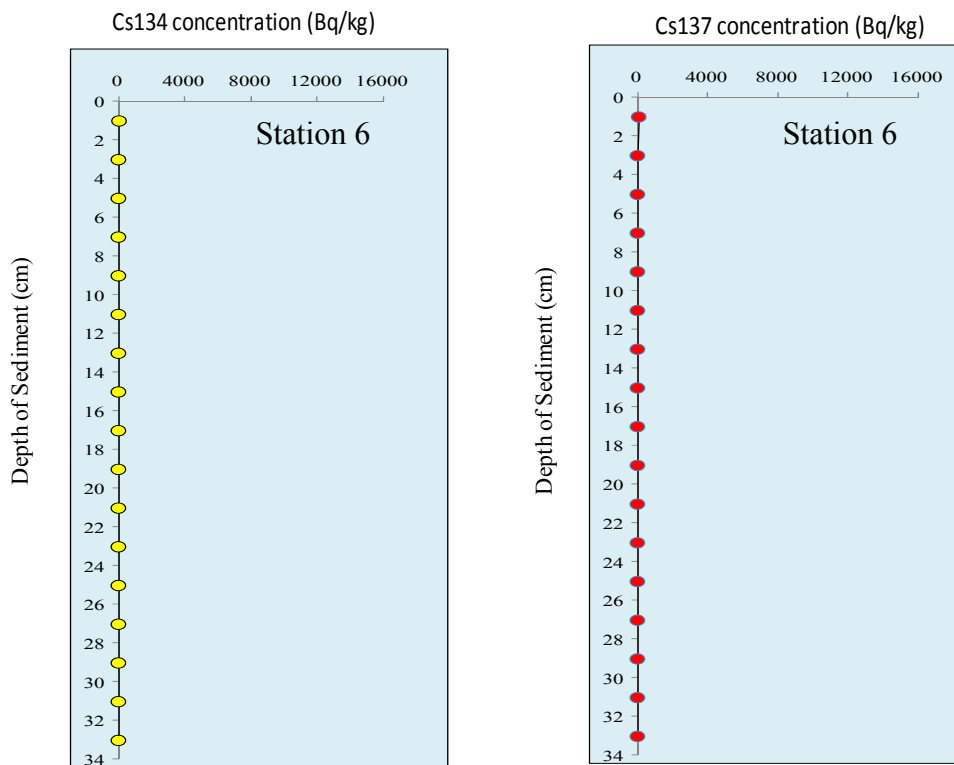


Fig.3.7(a). Vertical profile of  $^{134}\text{Cs}$  distribution in station 6

Fig.3.7(b). Vertical profile of  $^{137}\text{Cs}$  distribution in station 6

On 26th September samples were collected in 6 station ( include 1 station in upper part of river ) as Station 1,2,3,4,5 and Station 6, respectively.

In figure 3.8(a), 3.8(b),  $^{134}\text{Cs}$  and  $^{137}\text{Cs}$  concentration in station 1 the depth of cesium was 0 to 8cm with value from bottom to surface ranging from 56.61 Bq/kg to  $1.17 \times 10^2$  Bq/kg of  $^{134}\text{Cs}$  and the value of  $^{137}\text{Cs}$  ranging from  $1.15 \times 10^2$  Bq/kg to  $2.44 \times 10^3$  Bq/kg, respectively. high concentration was found in surface 0-2cm.

In figure 3.9(a), 3.9(b),  $^{134}\text{Cs}$  and  $^{137}\text{Cs}$  concentration in station 2 the depth of cesium was 0 to 10cm with value from bottom to surface ranging from  $2.9 \times 10^2$  Bq/kg to  $7.46 \times 10^2$  Bq/kg of  $^{134}\text{Cs}$  and the value of  $^{137}\text{Cs}$  ranging from  $5.44 \times 10^2$  Bq/kg to  $1.43 \times 10^3$  Bq/kg, respectively. high concentration was found in surface 2-4cm .

In figure 3.10(a), 3.10(b),  $^{134}\text{Cs}$  and  $^{137}\text{Cs}$  concentration in station 3 the depth of cesium was 0 to 8cm with value from bottom to surface ranging from 7.65 Bq/kg to  $8.92 \times 10^2$  Bq/kg of  $^{134}\text{Cs}$  and the value of  $^{137}\text{Cs}$  ranging from 20.80 Bq/kg to  $1.70 \times 10^3$  Bq/kg, respectively. high concentration also found in surface 2-4 cm.

In figure 3.11(a), 3.11(b),  $^{134}\text{Cs}$  and  $^{137}\text{Cs}$  concentration in station 4 the depth of cesium was 0 to 14 cm with value 53.48 Bq/kg to  $1.26 \times 10^3$  Bq/kg of  $^{134}\text{Cs}$  and the value of  $^{137}\text{Cs}$  were 90.85 Bq/kg to  $2.25 \times 10^3$  Bq/kg, respectively.

In figure 3.12(a), 3.12(b),  $^{134}\text{Cs}$  and  $^{137}\text{Cs}$  concentration in station 5 the depth of cesium was 0 to 14 cm with value minimum from  $1.32 \times 10^3$  Bq/kg to  $2.17 \times 10^3$  Bq/kg of  $^{134}\text{Cs}$  and the value of  $^{137}\text{Cs}$  were  $2.73 \times 10^3$  Bq/kg to  $3.91 \times 10^3$  Bq/kg, respectively. high concentration also found in surface 8-10 cm.

In figure 3.13(a), 3.13(b),  $^{134}\text{Cs}$  and  $^{137}\text{Cs}$  concentration in station 5 were found only in surface with the depth 0-2cm with the value of  $^{134}\text{Cs}$  and  $^{137}\text{Cs}$  were 37.44Bq/kg and 89.04 Bq/kg, respectively.

**Figures 3.8-3.9    SEPTEMBER 2012: Vertical distribution of <sup>134</sup>Cs and <sup>137</sup>Cs in core samples**

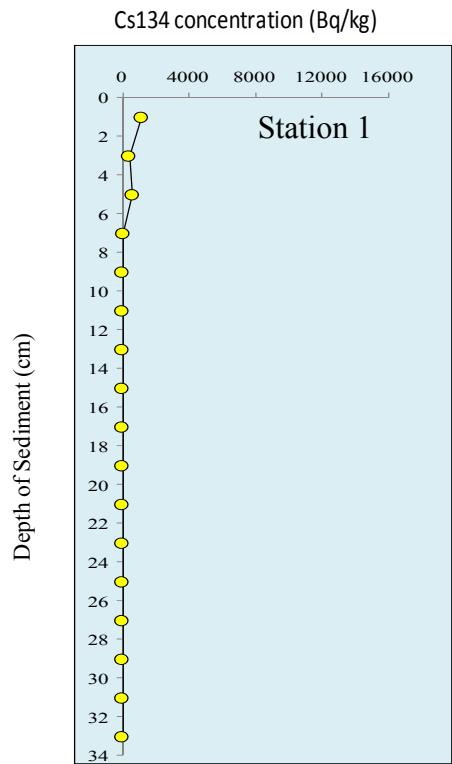


Fig.3.8(a). Vertical profile of Cs134 distribution in station 1

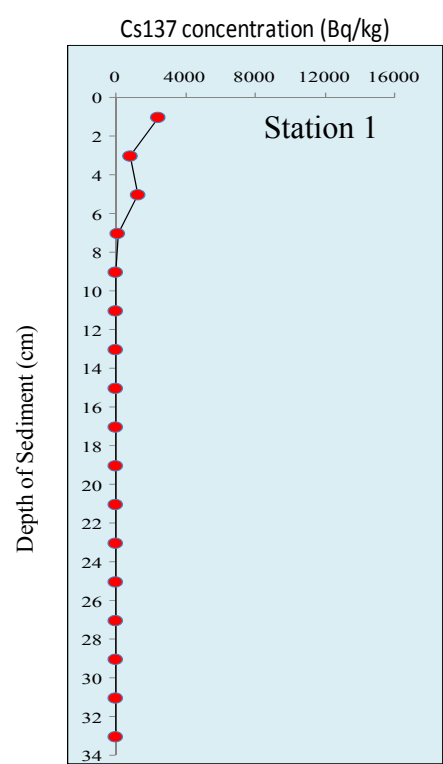


Fig.3.8(b). Vertical profile of Cs137 distribution in station 1

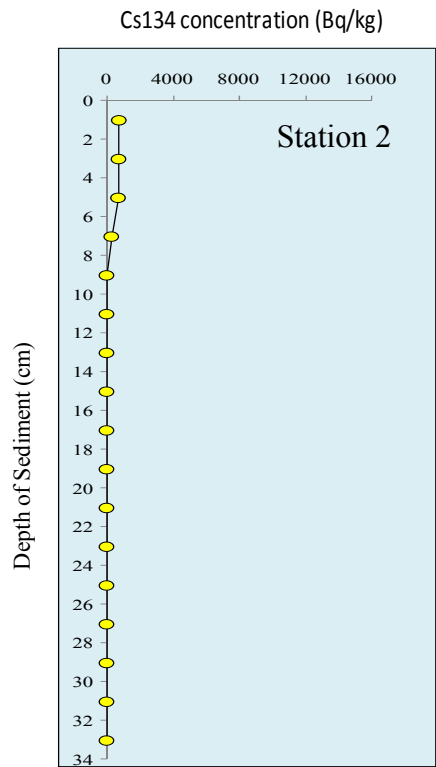


Fig.3.9(a). Vertical profile of Cs134 distribution in station 2

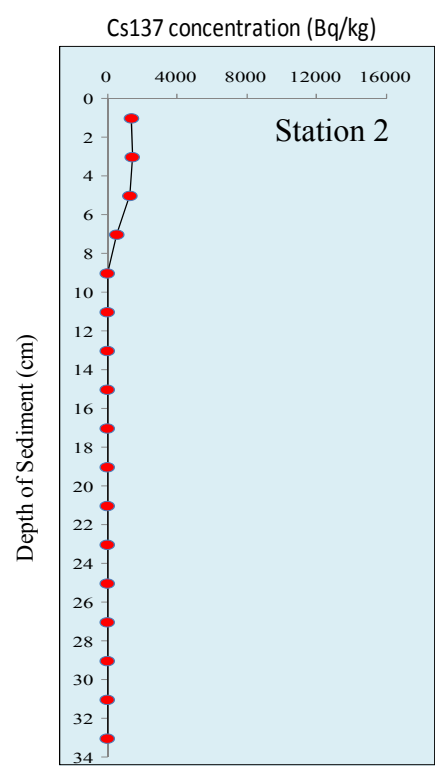


Fig.3.9(b). Vertical profile of Cs137 distribution in station 2

**Figure 3.10-3.11 SEPTEMBER 2012: Vertical distribution of  $^{134}\text{Cs}$  and  $^{137}\text{Cs}$  in core samples**

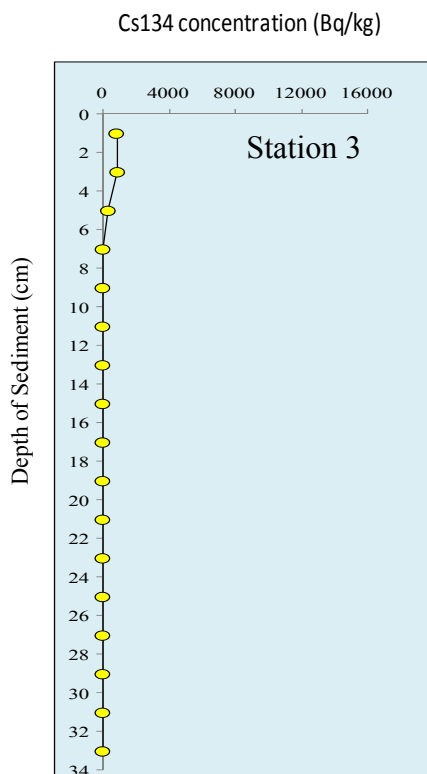


Fig.3.10(a). Vertical profile of  $^{134}\text{Cs}$  distribution in station 3

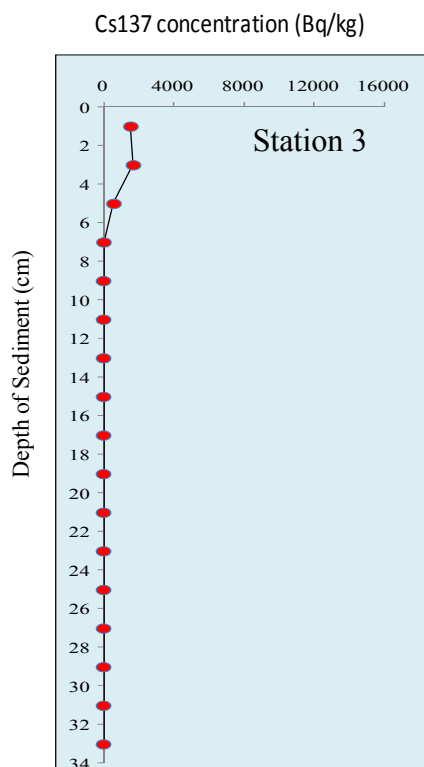


Fig.3.10(b). Vertical profile of  $^{137}\text{Cs}$  distribution in station 3

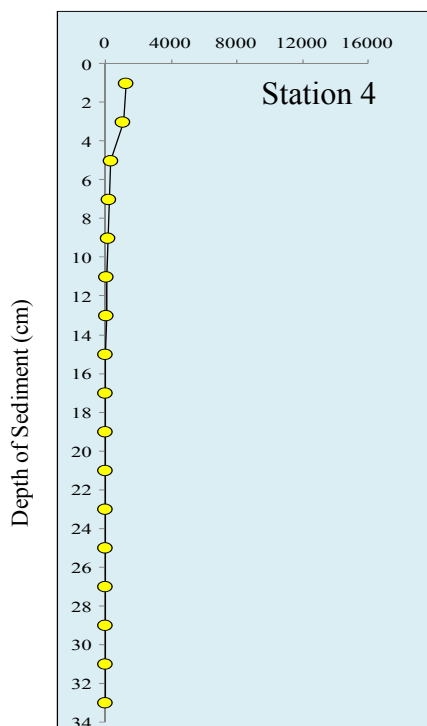


Fig.3.11(a). Vertical profile of  $^{134}\text{Cs}$  distribution in station 4

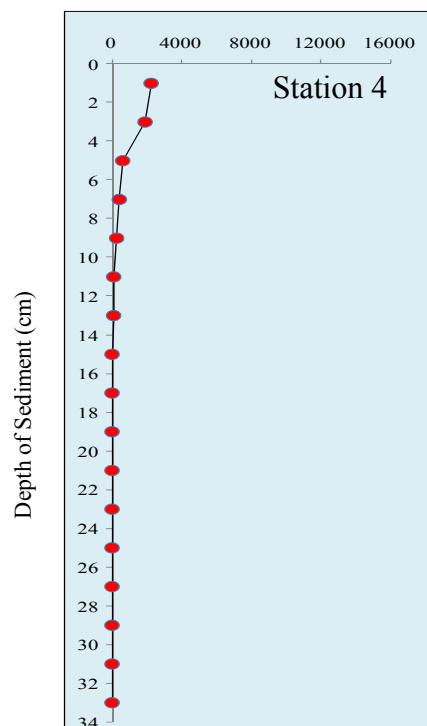


Fig.3.12(b). Vertical profile of  $^{137}\text{Cs}$  distribution in station 4

**Figure 3.12-3.13 SEPTEMBER 2012: Vertical distribution of  $^{134}\text{Cs}$  and  $^{137}\text{Cs}$  in core samples**

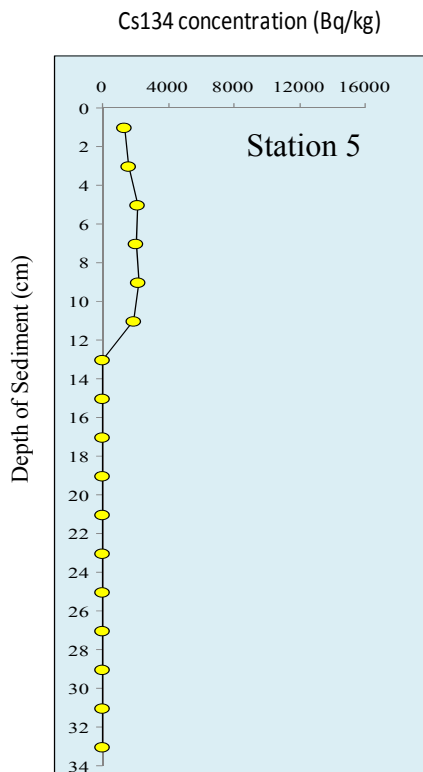


Fig.3.12(a). Vertical profile of  $^{134}\text{Cs}$  distribution in station 5

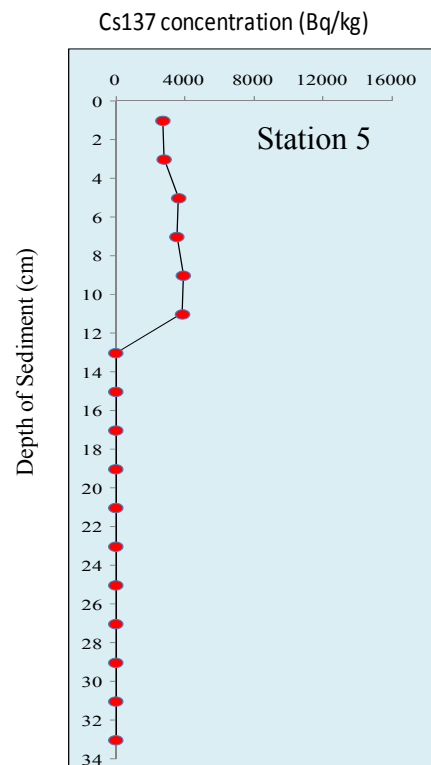


Fig.3.12(b). Vertical profile of  $^{137}\text{Cs}$  distribution in station 5

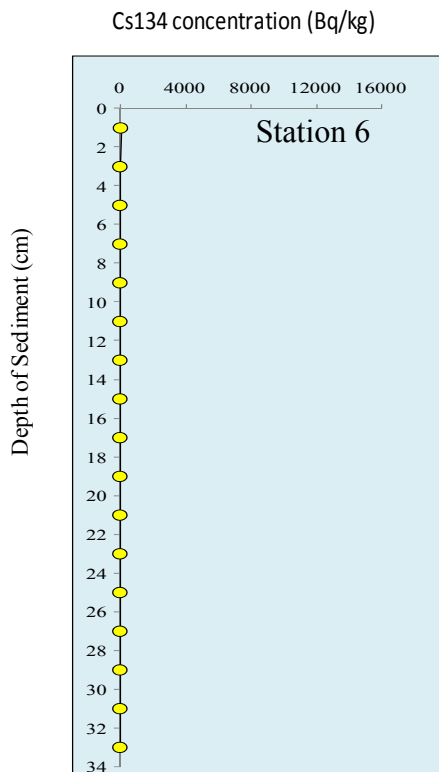


Fig.3.13(a). Vertical profile of  $^{134}\text{Cs}$  distribution in station 6

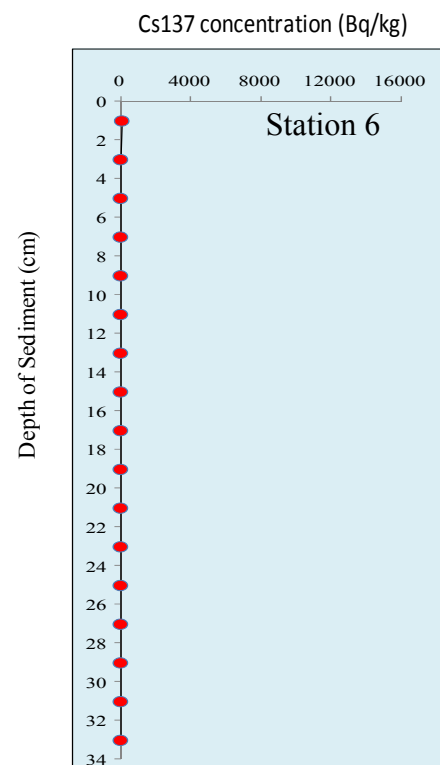


Fig.3.13(b). Vertical profile of  $^{137}\text{Cs}$  distribution in station 6

On 30th October, 6 station samples were collected in surface 3 cm and Core samples were collect only in Station 5 and Station 6. Figure 3.14(a) to 3.15(b) shown the result that depth of radiocesium in 2 stations were the same as 16 cm and this month in station 6 we found the concentration in this sample site were high and deposited compare to previous month . In station 5, two peaks of high concentrations were found at first peak the depth in 6cm the concentration of  $^{134}\text{Cs}$  were  $2.57 \times 10^3$  Bq/kg and  $^{137}\text{Cs}$   $5.62 \times 10^3$  Bq/kg and second peak in depth 12 cm the concentration  $^{134}\text{Cs}$  were  $2.85 \times 10^3$  Bq/kg and  $^{137}\text{Cs}$   $6.03 \times 10^3$  Bq/kg. In station 6, we found the high concentration in the depth 8 cm. the concentration of  $^{134}\text{Cs}$  were  $1.70 \times 10^3$  Bq/kg and  $^{137}\text{Cs}$   $3.31 \times 10^3$  Bq/kg.

As the result in this month shown that, in station 5 were found 2 peaks of high concentration and the concentration of radiocesium in station 6 were found in the depth 18 cm and was high in the depth 8 cm.



**Figure 3.14-3.15 OCTOBER 2012: Vertical distribution of  $^{134}\text{Cs}$  and  $^{137}\text{Cs}$  in core samples**

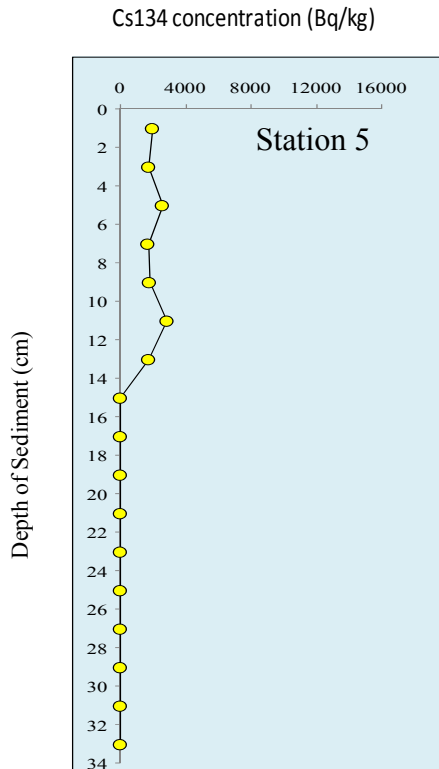


Fig.3.14(a). Vertical profile of  $^{134}\text{Cs}$  distribution in station 5

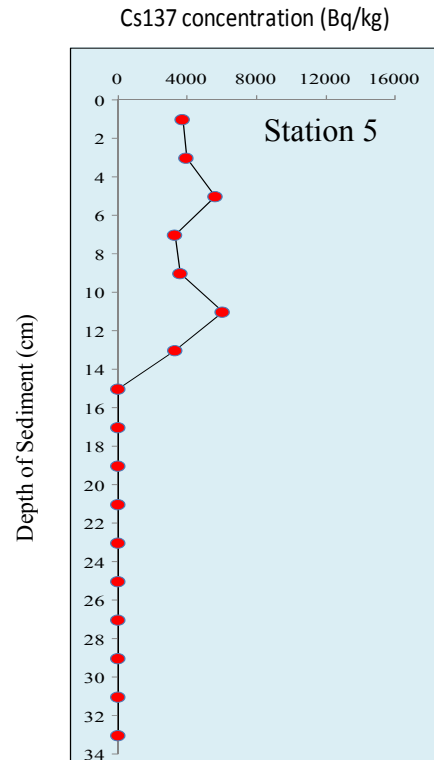


Fig.3.14(b). Vertical profile of  $^{137}\text{Cs}$  distribution in station 5

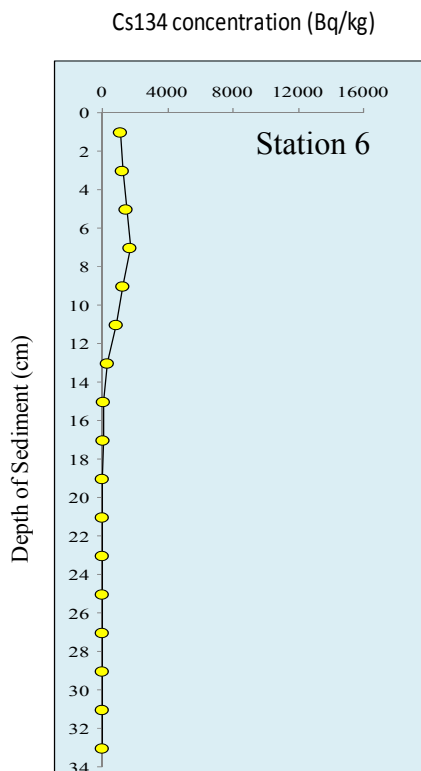


Fig.3.15(a). Vertical profile of  $^{134}\text{Cs}$  distribution in station 6

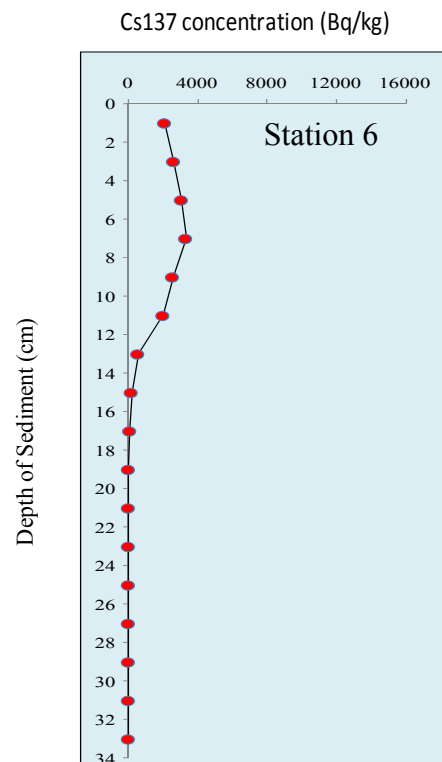
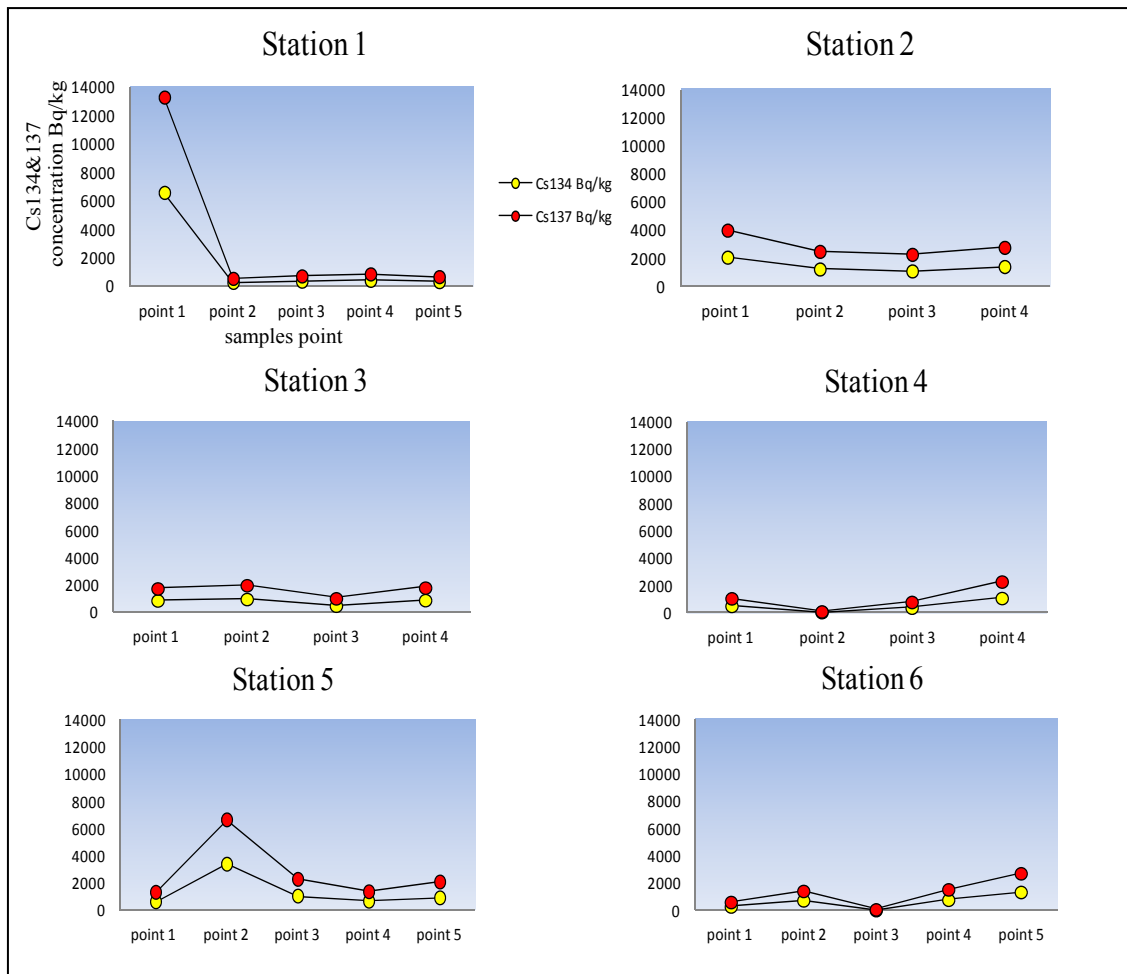


Fig.3.15(b). Vertical profile of  $^{137}\text{Cs}$  distribution in station 6



**Figure 3.16 Counter-checking different concentrations of radiocesium in same station.**

The result in this figure shown on the concentration of Cs134 and Cs137 in each points of 6 station were collected in October 2012 from left bank to right bank of river, to consider on the concentration distribution around each station and the result shown that, concentration almost the same in each point but we found that in station 1 near the left bank of river(point 1) and Station 5 in middle part of river (point 2)concentration quite higher then another point.

### **3.1.2 Vertical distribution of $^{134}\text{Cs}$ and $^{137}\text{Cs}$ in Core samples lower part of river**

On 31th of November and 28th of December were started to collect the core samples in 5 stations (Station 7,8,9,10 and 11) of lower part of river. In November, the radiocesium was found highest value in each station were Station 7 of depth 14-16 cm and Station 8 of depth 4-6 cm (figure 3.17(a) to 3.34(b)), Station 9 of depth 12-14 cm and Station 11 of depth 14-16 cm (figure 3.35(a) to 3.38(b)), respectively. In December, 3 peaks was found in station 9, the peak was 12-14 cm, second peak 24-26cm and third peak 4-6 cm (figure 3.39(a) -3.40(b)), respectively. However, station 10 was selected in middle between Station 9 and station 11. The highest value in station 10 was found of depth 4-6 cm.

As the result in 2 months shown that, Station 9 were found 3 peaks in this station and highest value were found in sediment depth from 4-26 cm. in case of 5 stations in lower part of river, the deposited and concentration of radiocesium were highest value compare to upper part.

**Figure 3.17-3.18 NOVEMBER 2012: Vertical distribution of  $^{134}\text{Cs}$  and  $^{137}\text{Cs}$  in core samples**

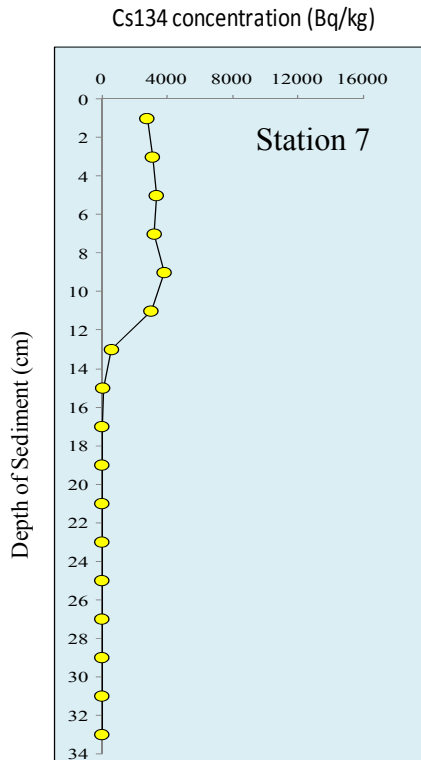


Fig.3.17 (a). Vertical profile of  $^{134}\text{Cs}$  distribution in station 7

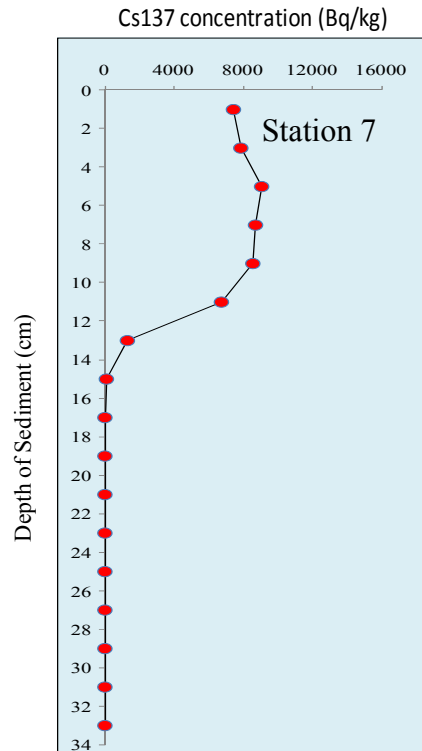


Fig.3.17(b). Vertical profile of  $^{137}\text{Cs}$  distribution in station 7

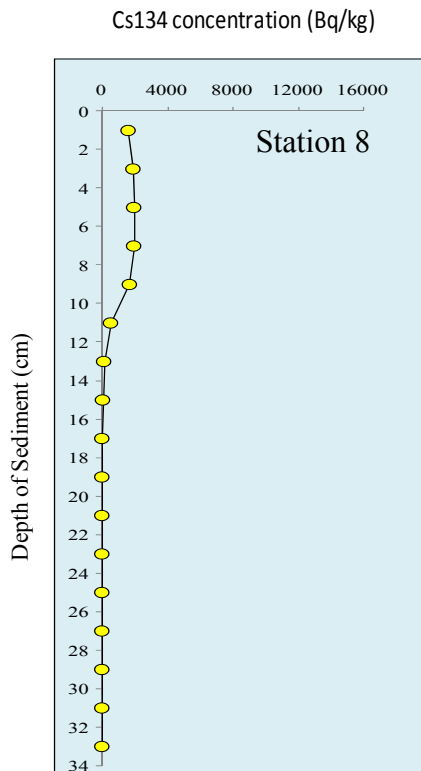


Fig.3.18(a). Vertical profile of  $^{134}\text{Cs}$  distribution in station 8

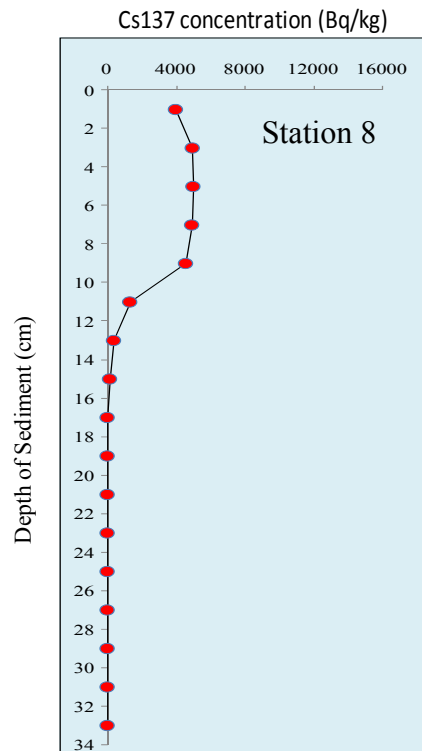


Fig.3.18(b). Vertical profile of  $^{137}\text{Cs}$  distribution in station 8

**Figure 3.19-3.20 NOVEMBER 2012: Vertical distribution of  $^{134}\text{Cs}$  and  $^{137}\text{Cs}$  in core samples**

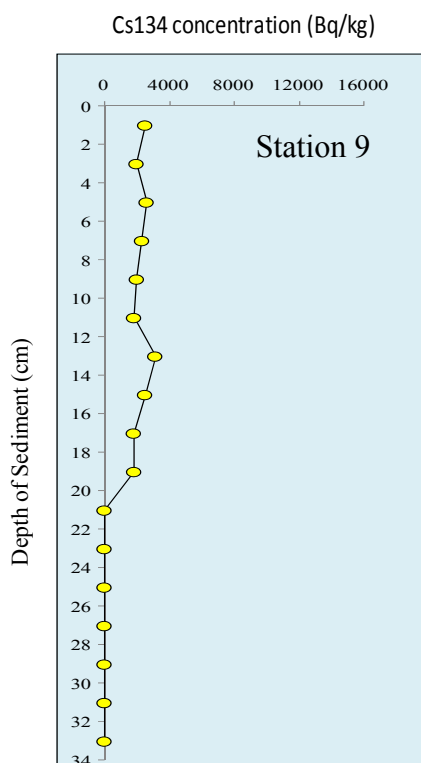


Fig.3.19 (a). Vertical profile of  $^{134}\text{Cs}$  distribution in station 9

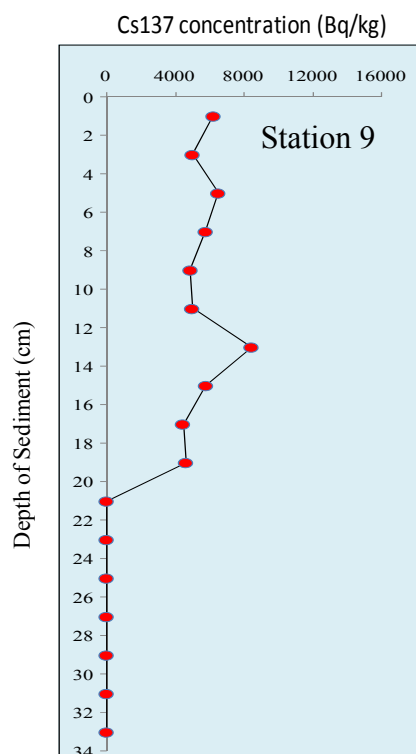


Fig.3.19(b). Vertical profile of  $^{137}\text{Cs}$  distribution in station 9

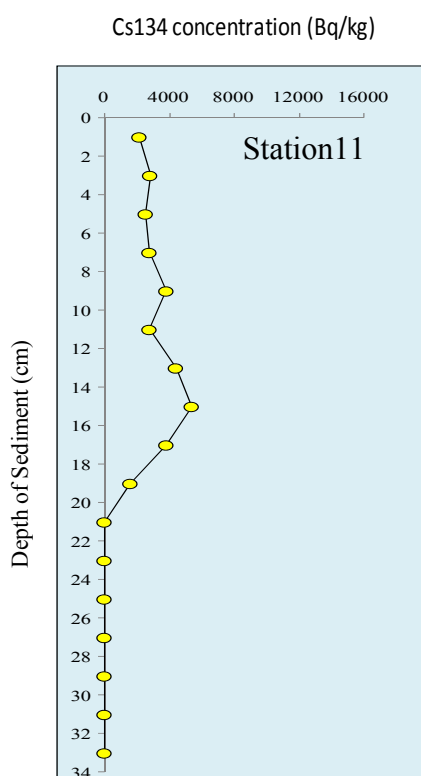


Fig.3.20(a). Vertical profile of  $^{134}\text{Cs}$  distribution in station 11

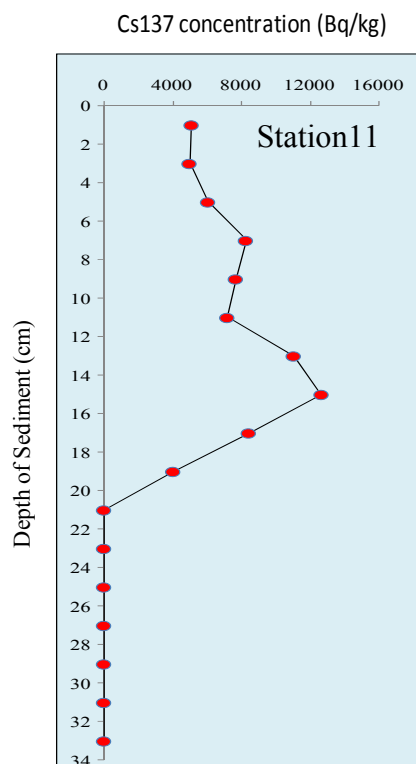


Fig.3.21(b). Vertical profile of  $^{137}\text{Cs}$  distribution in station 11

**Figure 3.21-3.22 DECEMBER2012: Vertical distribution of  $^{134}\text{Cs}$  and  $^{137}\text{Cs}$  in core samples**

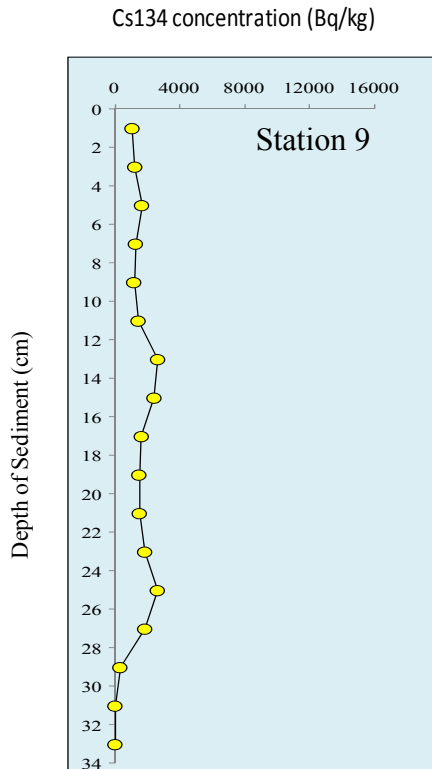


Fig.3.21 (a). Vertical profile of  $^{134}\text{Cs}$  distribution in station 9

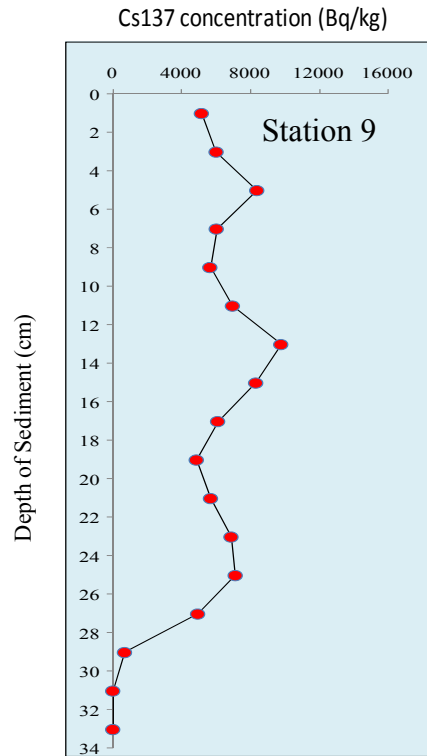


Fig.3.21(b). Vertical profile of  $^{137}\text{Cs}$  distribution in station 9

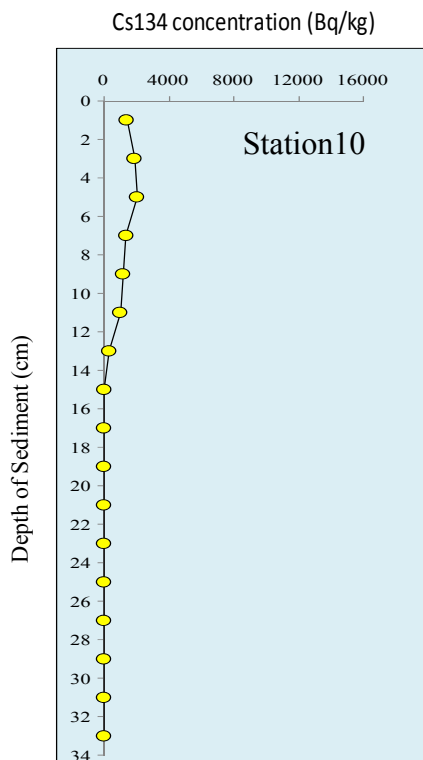


Fig.3.22(a). Vertical profile of  $^{134}\text{Cs}$  distribution in station 10

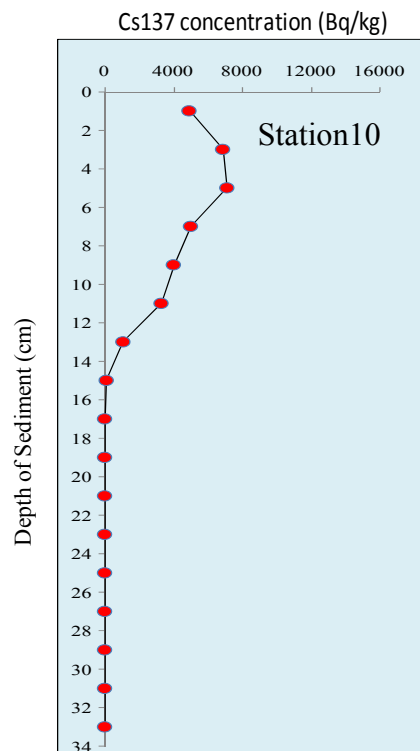


Fig.3.22(b). Vertical profile of  $^{137}\text{Cs}$  distribution in station 10

**Figure 3.23-3.24 DECEMBER2012: Vertical distribution of  $^{134}\text{Cs}$  and  $^{137}\text{Cs}$  in core samples**

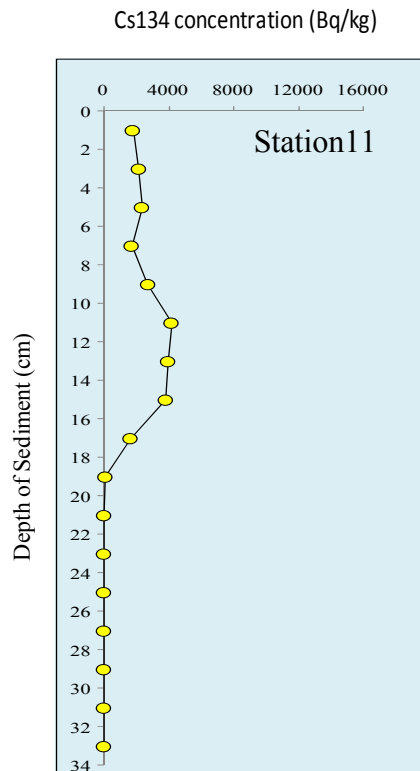


Fig.3.23 (a). Vertical profile of  $^{134}\text{Cs}$  distribution in station 11

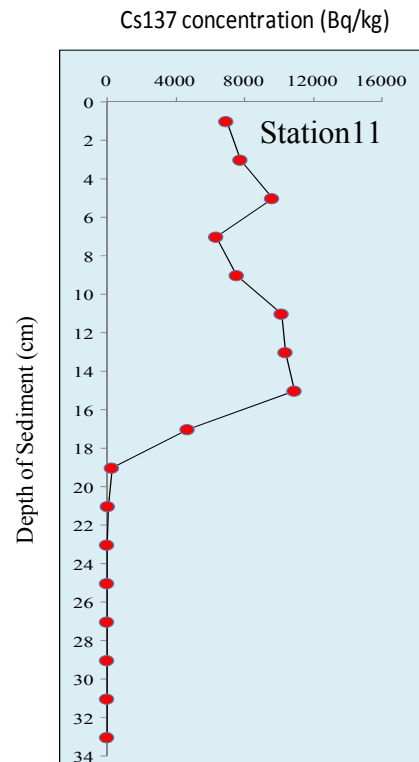


Fig.3.23(b). Vertical profile of  $^{137}\text{Cs}$  distribution in station 11

## 3.2 Radionuclide ( $^{134}\text{Cs}$ and $^{137}\text{Cs}$ ) concentration analysis of Ohori River in 2013

### 3.2.1 Distribution of Cesium Radionuclides in surface land soil of Ohori basin

On June 2013, surface soil samples was collected and measured in 20 point around Ohori basin. The distribution of  $^{134}\text{Cs}$  and  $^{137}\text{Cs}$  around Ohori basin was shown in figure 3.45, the radiocesium concentration ( $^{134}\text{Cs} + ^{137}\text{Cs}$ ) varied from 36.72 Bq/kg to 15217.06 Bq/kg, respectively. The highest value were found in point 5 and point 14 (around Kashiwanoha campus area) and concentration radiocesium were 15217.06 Bq/kg and 13621.38 Bq/kg, respectively.



Figure 3.24 Distribution of radiocesium in soil surface land of Ohori basin

### 3.2.2 Distribution of $^{134}\text{Cs}$ and $^{137}\text{Cs}$ in Core samples upper part of river

In figure 3.46(a) to 3.51(b) show that, in station 1 the highest concentration was found at depth of surface sediment 0-2 cm and gradually decreased to down ward of 6-8 cm. Cesium concentration of 6-8 cm is the almost same in station 1 and station 3. In station 5, highest value was found in 10-12 cm.



**Figure 3.24-3.25 MARCH 2013: Vertical distribution of  $^{134}\text{Cs}$  and  $^{137}\text{Cs}$  in core samples**

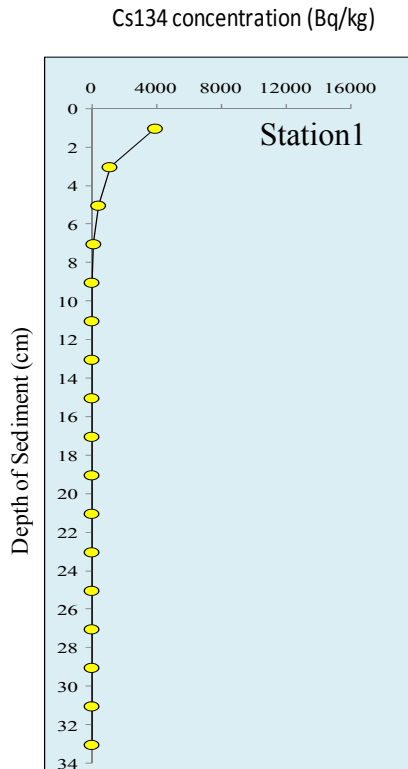


Fig.3.24 (a). Vertical profile of Cs134 distribution in station 1

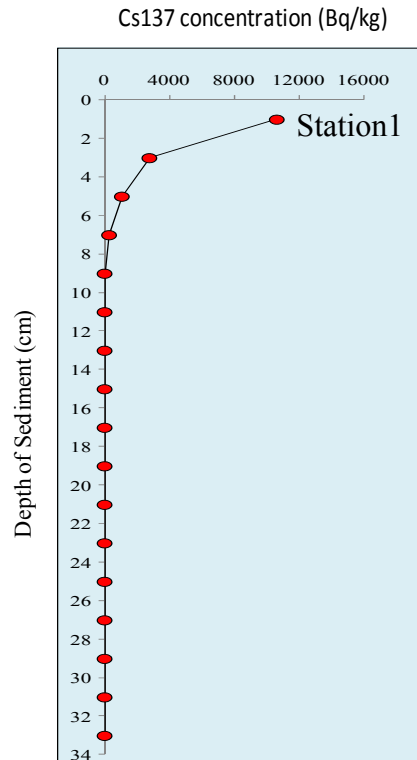


Fig.3.24(b). Vertical profile of Cs137 distribution in station 1

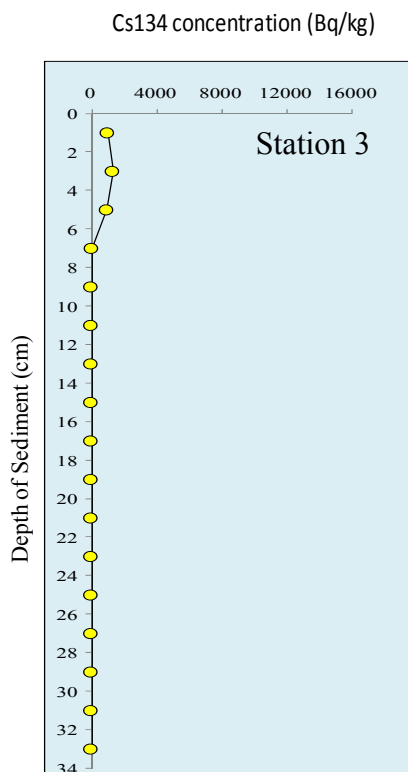


Fig.3.25 (a). Vertical profile of Cs134 distribution in station 3

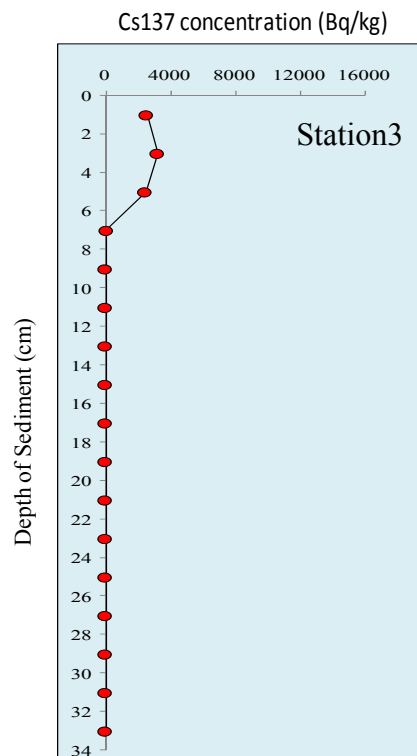


Fig.3.25(b). Vertical profile of Cs137 distribution in station 3

**Figure 3.26 MARCH 2013: Vertical distribution of  $^{134}\text{Cs}$  and  $^{137}\text{Cs}$  in core samples**

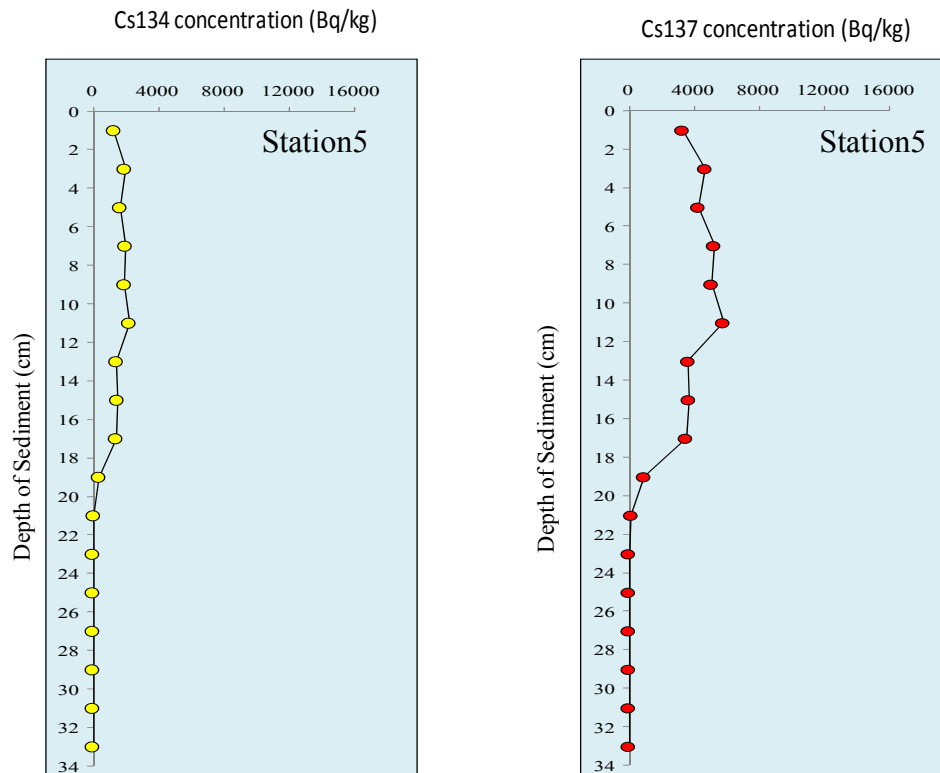


Fig.3.26 (a). Vertical profile of Cs134 distribution in station 5

Fig.3.26(b). Vertical profile of Cs137 distribution in station 5

### **3.2.3 Distribution of $^{134}\text{Cs}$ and $^{137}\text{Cs}$ in Core samples lower part of river**

Observation results, in the lower part of river were found that , in station 9 the concentration of radiocesium was decreased and we could not find any peak in this time (figure 3.52(a) and 3.53(b)). In station 10 and 11 (figure 3.54(a) and 3.57(b)) shown clearly that, the highest values were found of depth 6-8cm in both stations. However, 2 peaks were found in station 11 of depth 6-8cm and 10-12cm, respectively.

**Figure 3.26-27 MARCH 2013: Vertical distribution of  $^{134}\text{Cs}$  and  $^{137}\text{Cs}$  in core samples**

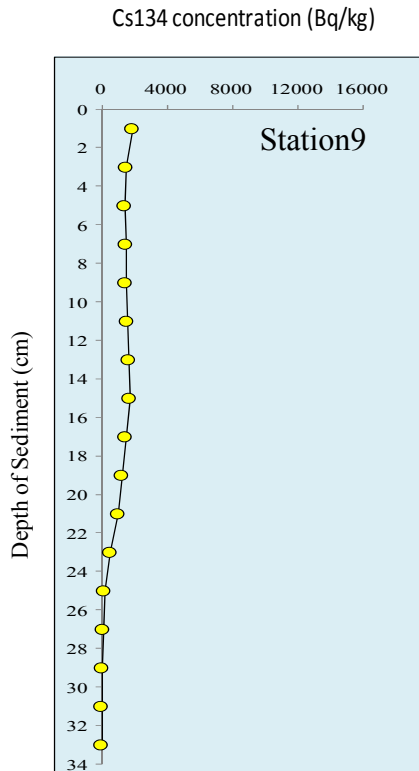


Fig.3.26 (a). Vertical profile of Cs134 distribution in station 9

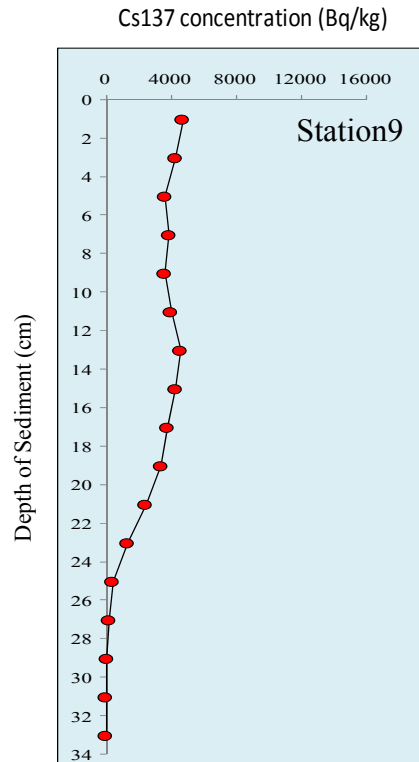


Fig.3.26(b). Vertical profile of Cs137 distribution in station 9

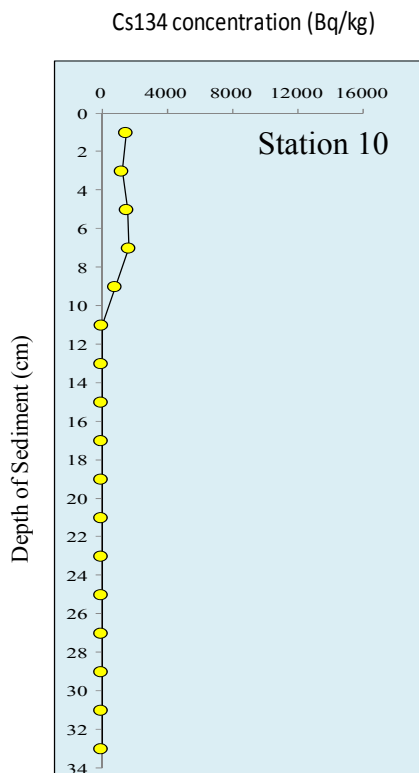


Fig.3.27 (a). Vertical profile of Cs134 distribution in station 10

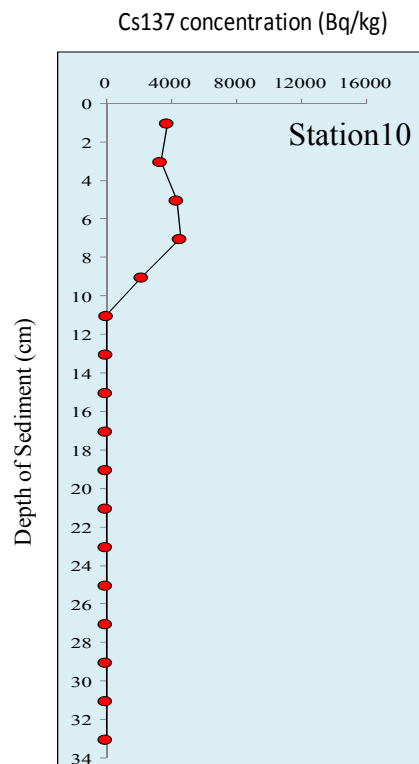


Fig.3.27(b). Vertical profile of Cs137 distribution in station 10

**Figure 28 MARCH 2013: Vertical distribution of  $^{134}\text{Cs}$  and  $^{137}\text{Cs}$  in core samples**

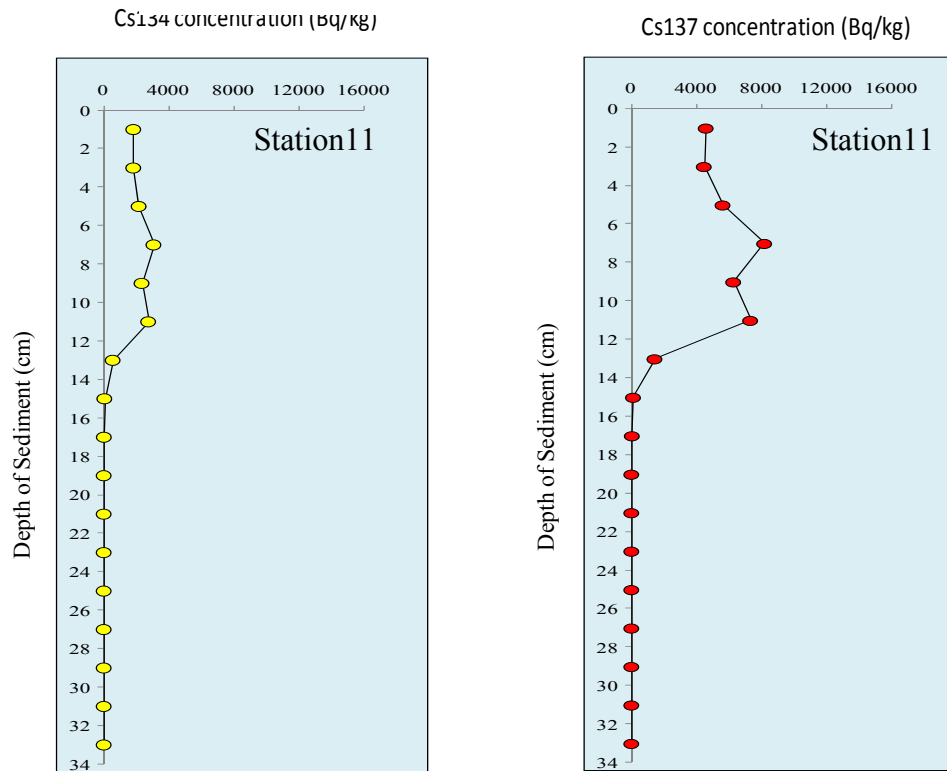
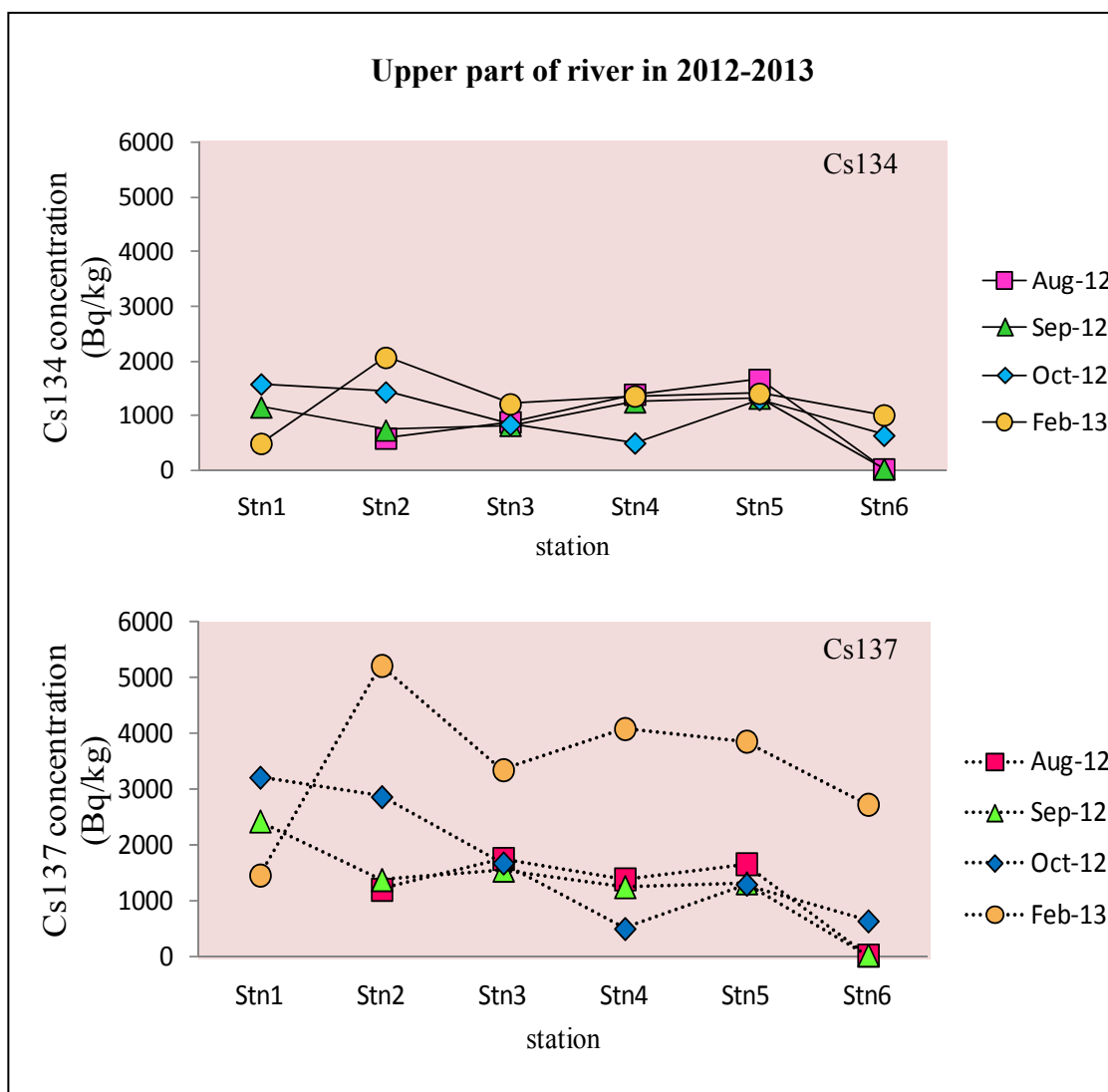


Fig.3.28 (a). Vertical profile of  $^{134}\text{Cs}$  distribution in station 11

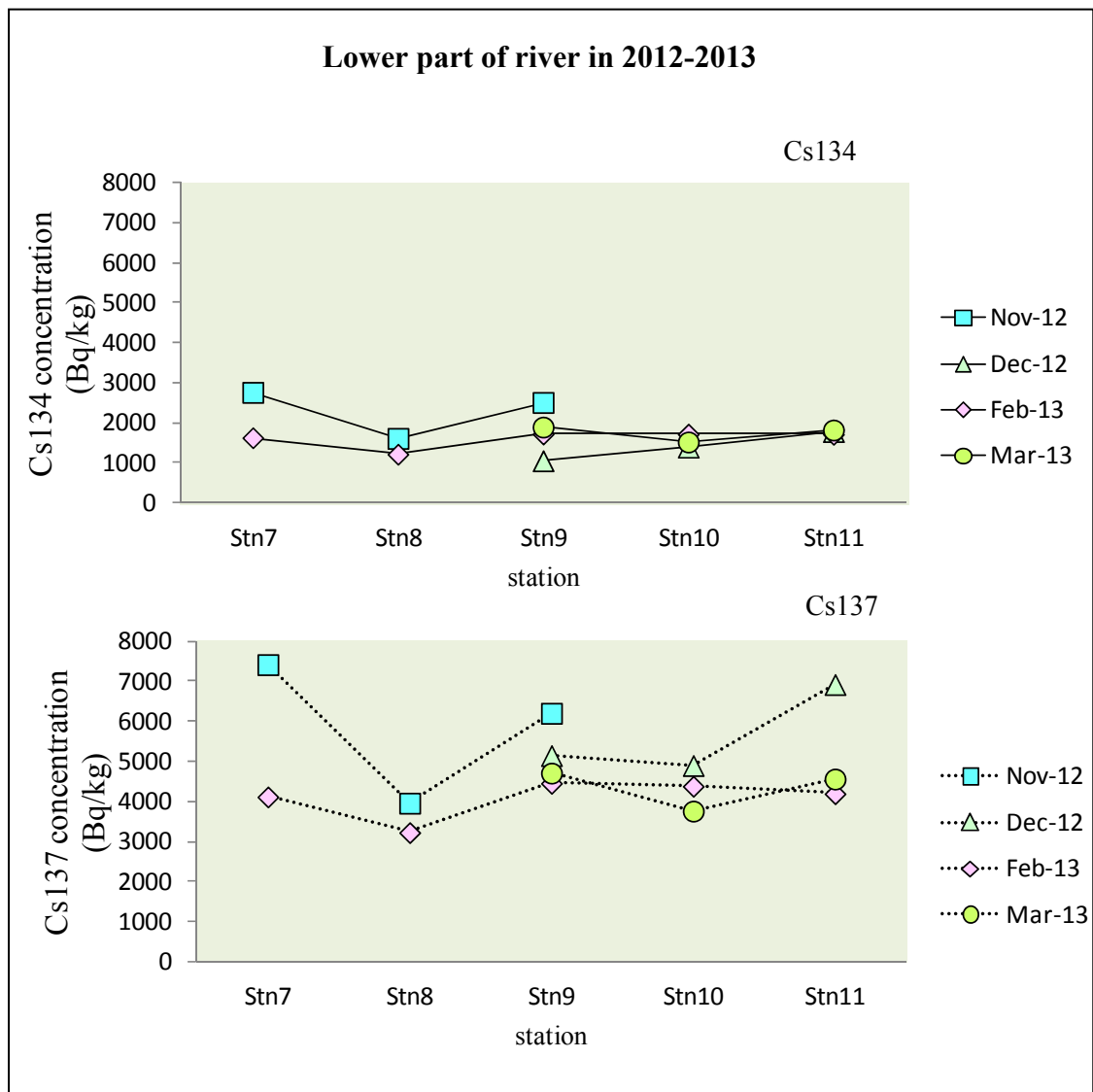
Fig.3.28(b). Vertical profile of  $^{137}\text{Cs}$  distribution in station 11

### 3.2.4 Time variation of $^{134}\text{Cs}$ and $^{137}\text{Cs}$ in surface of sediment Ohori river



**Figure 29. Time variation of  $^{134}\text{Cs}$  and  $^{137}\text{Cs}$  in the upper surface of sediment Ohori river**

Fig.3.29 The result in this figure shown on the time variation of radiocesium in surface sediment in station 1 until station 6 in upper part of river,  $^{134}\text{Cs}$  concentration in station 1 was decreased in February 2013 and increased in station 2 and 6, respectively. In case of  $^{137}\text{Cs}$  were found that in station 1 was decreased but in station 2 until station 6 were increased.



**Figure 30 Time variation of <sup>134</sup>Cs and <sup>137</sup>Cs in the lower part surface of sediment Ohori river**

Fig.3.30 The result in this figure shown on the time variation of radiocesium in surface sediment in station 7 until station 11 in lower part of river, as the result shown that, on March 2013 in station 9,10 and 11 the concentration almost constant and not change so much .

### **3.3 Radiocesium ( $^{134}\text{Cs}$ and $^{137}\text{Cs}$ ) concentration analysis of Teganuma Lake in 2012-2013**

#### **3.3.1 Vertical distribution of $^{134}\text{Cs}$ and $^{137}\text{Cs}$ in Core samples 2012-2013**

Vertical profiles at the 7 station in Teganuma lake as shown as follows field observation . Data was started from 17 October 2012, In Figure 3.31(a)-3.37(b) shown that in station 1 located in river mouth, the highest value were found of depth 9-12cm and depth of concentration was deposited in 18-21 cm of depth sediment profile and station 2,3,4 and 5 were located in middle part of lake the depth sediment profile were found in 0-9 cm, respectively. In lower part of lake station 6 and 7 were found only in surface sediment of depth 0-3 cm. the concentration was high value in station 1 and 5 as located in river mouth and middle part of lake.

On March and May 2013 sediment core samples were collected and measured again. The result shown that, in station 1 concentration was found the highest value in the surface of depth 0-3 cm and decreased in depth of 3-6 cm show in Figure 3.35(a)-3.35(b), respectively. The concentration within 2 months almost the same in each station and the highest concentration point almost the same in 2012 as found in station 1 and 5.



**Figure 3.31-3.32 OCTOBER 2012: Vertical distribution of  $^{134}\text{Cs}$  and  $^{137}\text{Cs}$  in core samples**

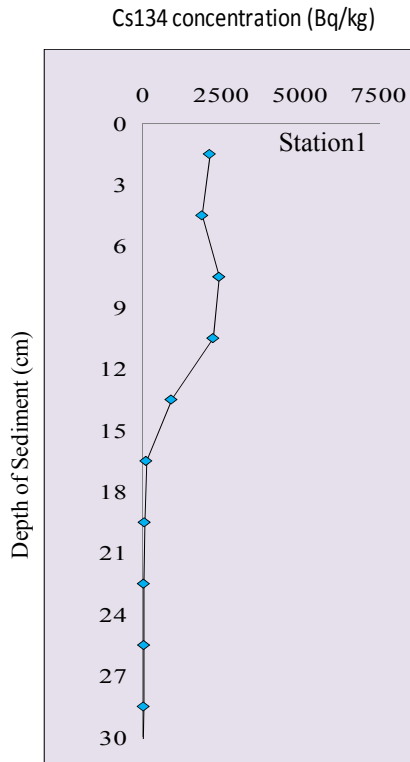


Fig.3.31 (a). Vertical profile of  $^{134}\text{Cs}$  distribution in station 1

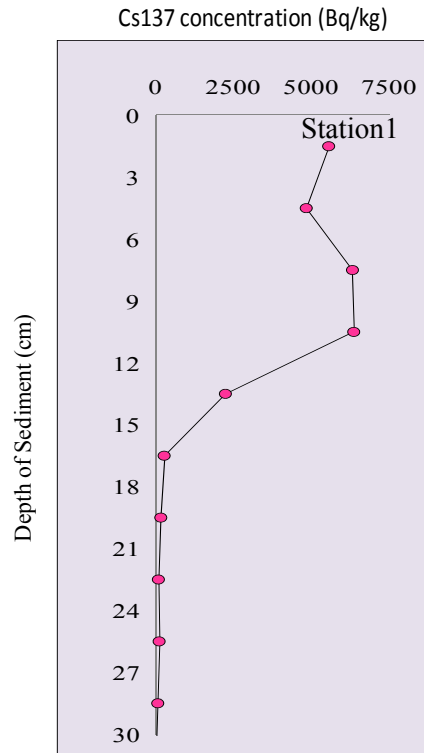


Fig.3.31(b). Vertical profile of  $^{137}\text{Cs}$  distribution in station 1

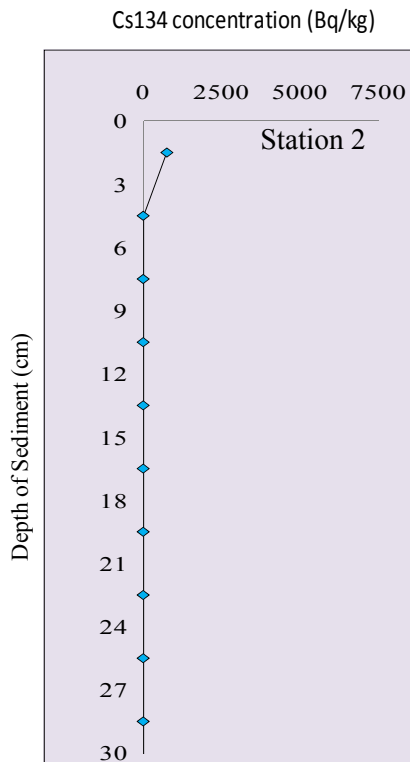


Fig.3.32 (a). Vertical profile of  $^{134}\text{Cs}$  distribution in station 2

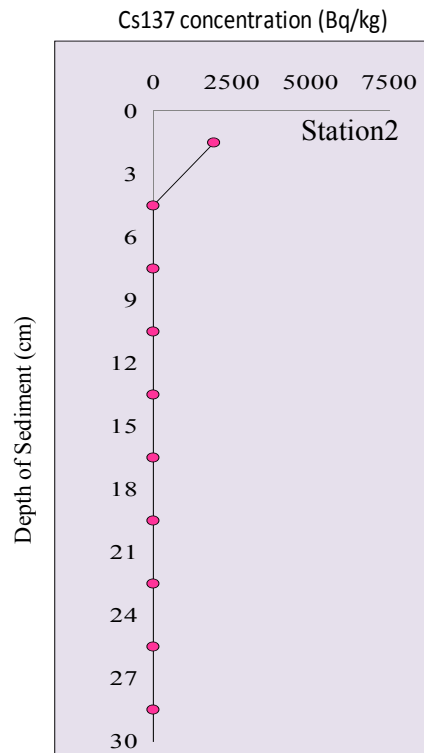


Fig.3.32(b). Vertical profile of  $^{137}\text{Cs}$  distribution in station 2

**Figure 3.33-3.34 OCTOBER 2012: Vertical distribution of  $^{134}\text{Cs}$  and  $^{137}\text{Cs}$  in core samples**

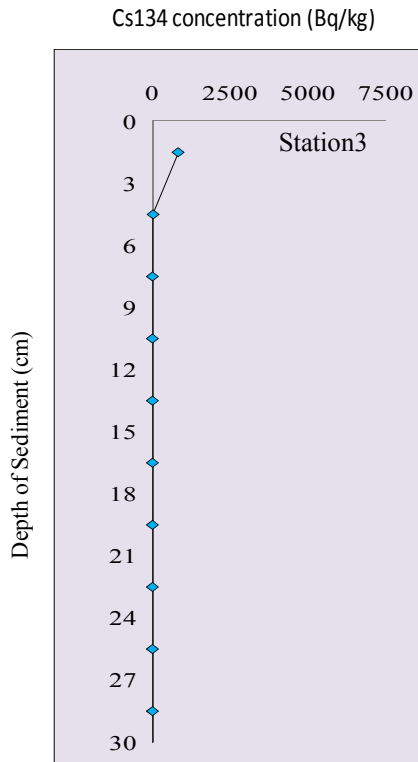


Fig.3.33(a). Vertical profile of  $^{134}\text{Cs}$  distribution in station 3

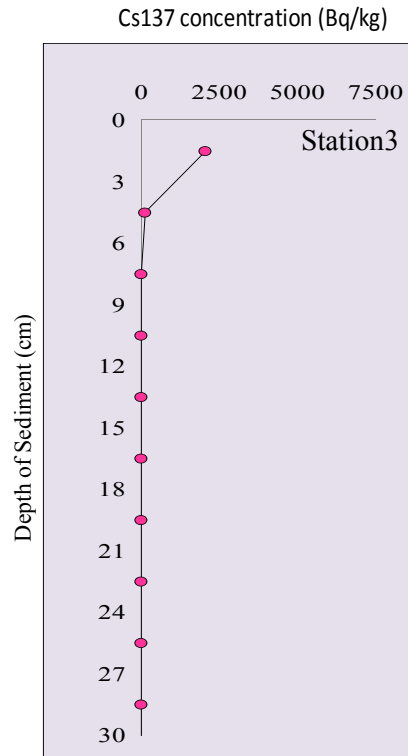


Fig.3.33(b). Vertical profile of  $^{137}\text{Cs}$  distribution in station 3

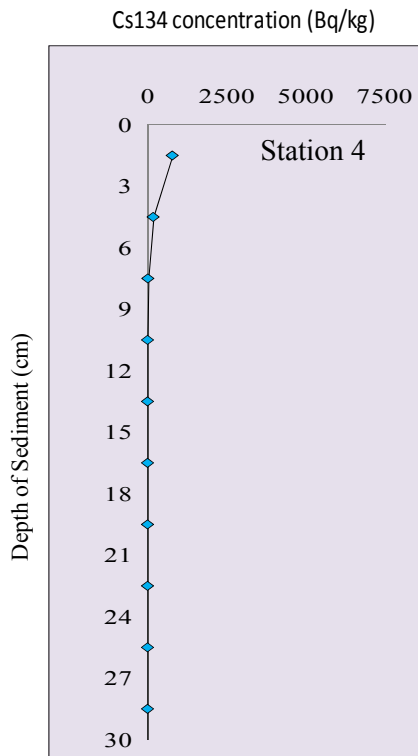


Fig.3.34(a). Vertical profile of  $^{134}\text{Cs}$  distribution in station 4

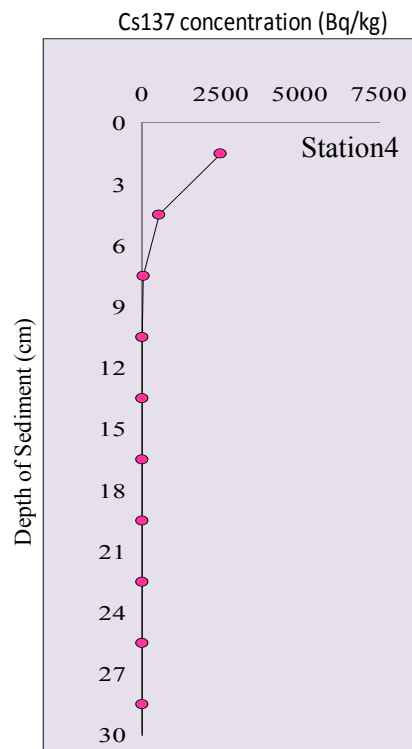


Fig.3.34(b). Vertical profile of  $^{137}\text{Cs}$  distribution in station 4

**Figure 3.35-3.36 OCTOBER 2012: Vertical distribution of  $^{134}\text{Cs}$  and  $^{137}\text{Cs}$  in core samples**

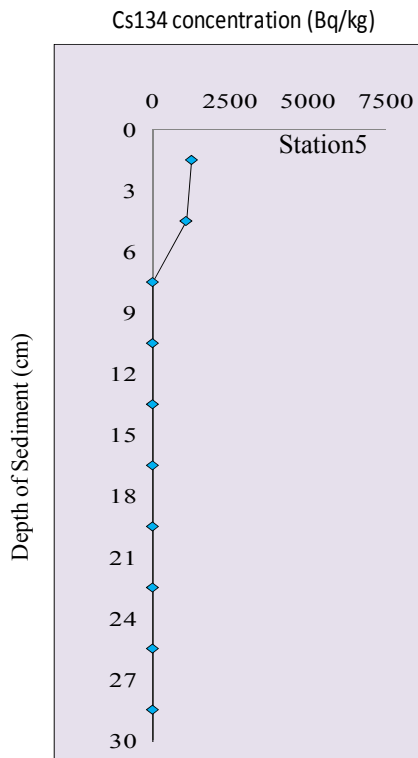


Fig.3.35(a). Vertical profile of  $^{134}\text{Cs}$  distribution in station 5

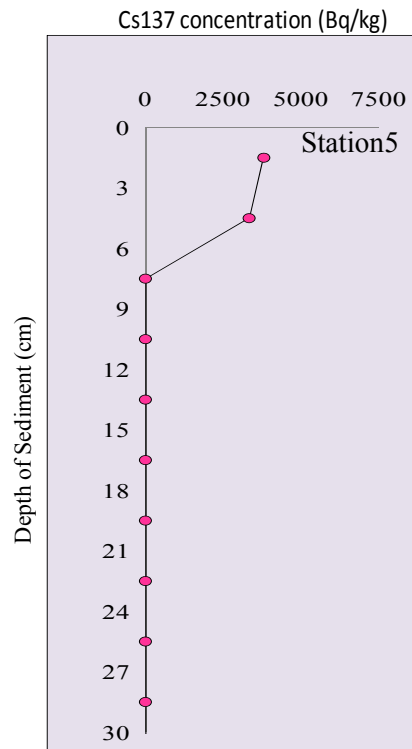


Fig.3.35(b). Vertical profile of  $^{137}\text{Cs}$  distribution in station 5

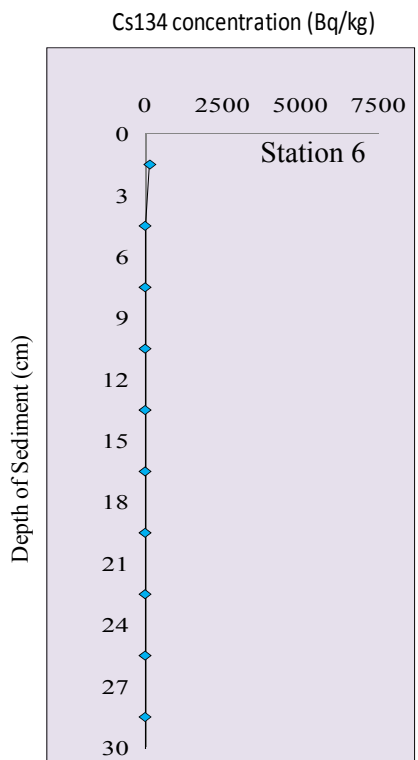


Fig.3.36 (a). Vertical profile of  $^{134}\text{Cs}$  distribution in station 6

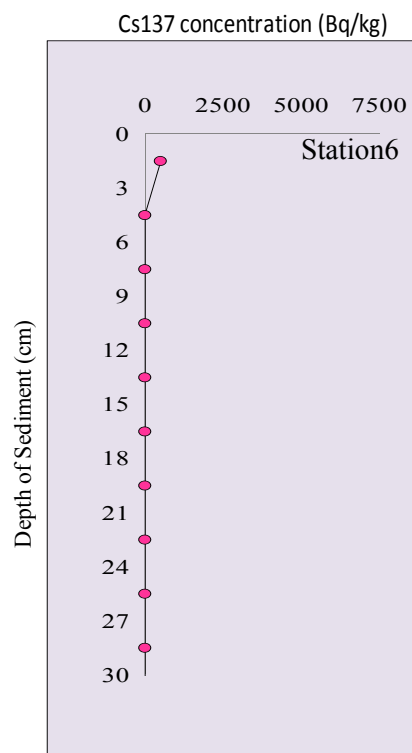


Fig.3.36(b). Vertical profile of  $^{137}\text{Cs}$  distribution in station 6

**Figure 37    OCTOBER 2012: Vertical distribution of  
134Cs and 137Cs in core samples**

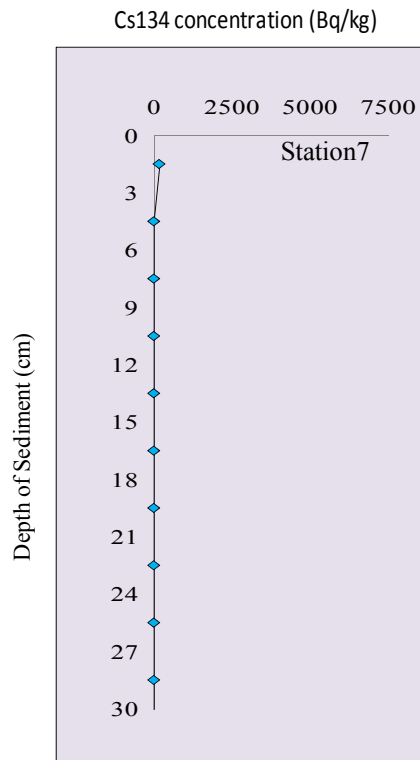


Fig.3.37(a). Vertical profile of Cs134 distribution in station 7

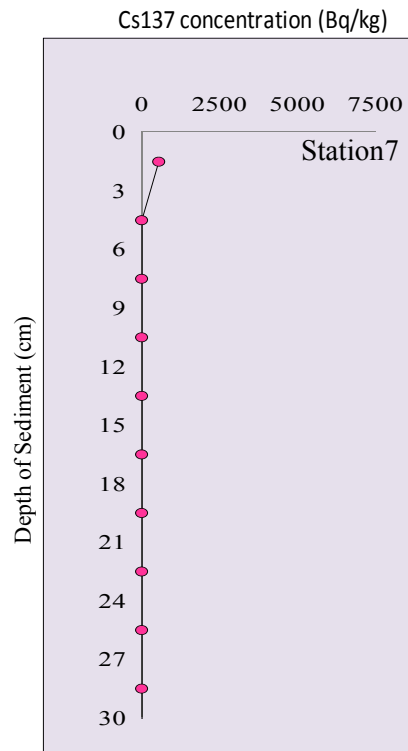


Fig.3.37(b). Vertical profile of Cs137 distribution in station 7

**Figure 3.38 MARCH 2013: Vertical distribution of  $^{134}\text{Cs}$  and  $^{137}\text{Cs}$  in core samples**

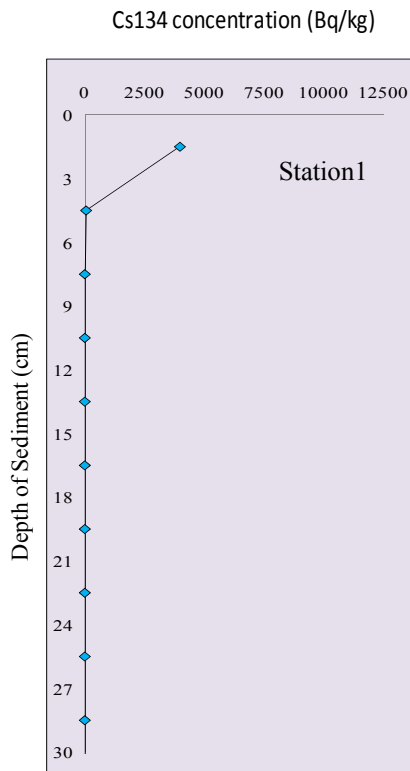


Fig.3.38(a). Vertical profile of  $^{134}\text{Cs}$  distribution in station 1

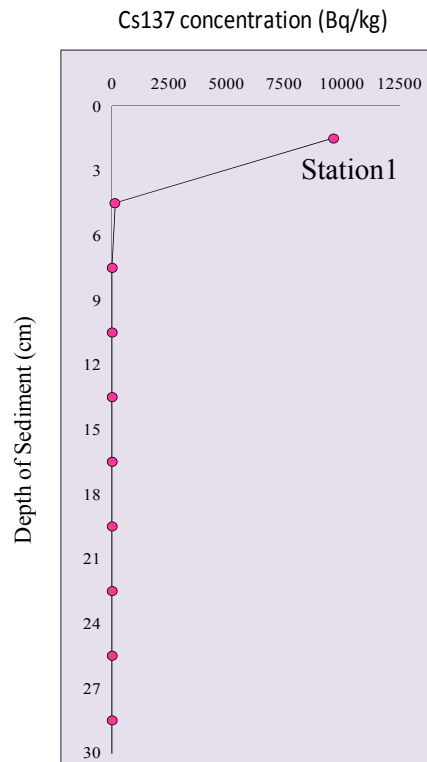


Fig.3.38(b). Vertical profile of  $^{137}\text{Cs}$  distribution in station 1

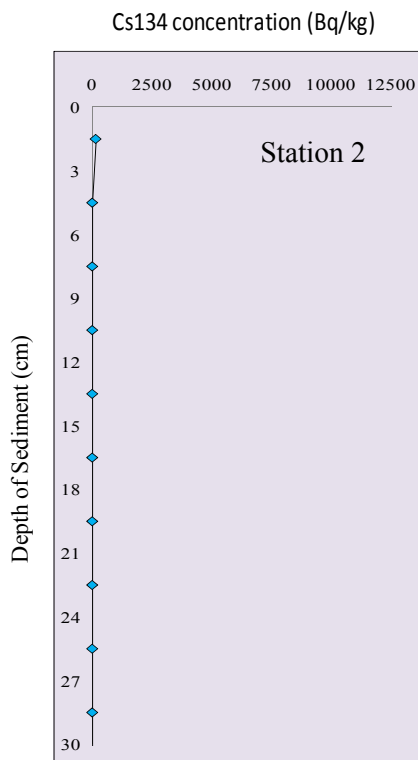


Fig.3.38 (a). Vertical profile of  $^{134}\text{Cs}$  distribution in station 2

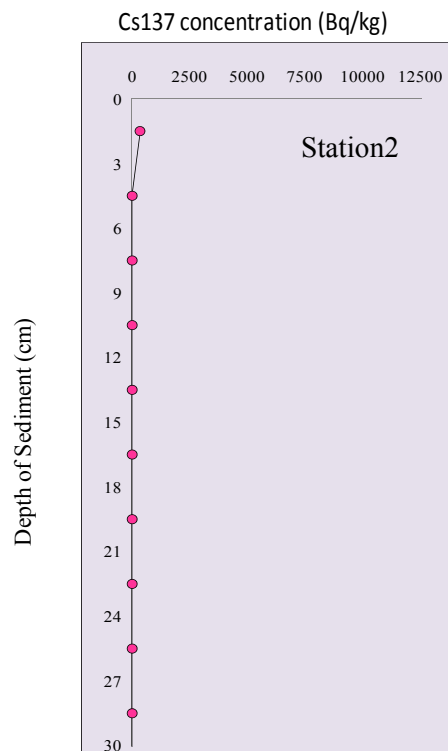


Fig.3.38(b). Vertical profile of  $^{137}\text{Cs}$  distribution in station 2

**Figure 3.39-3.40 MARCH 2013: Vertical distribution of  $^{134}\text{Cs}$  and  $^{137}\text{Cs}$  in core samples**

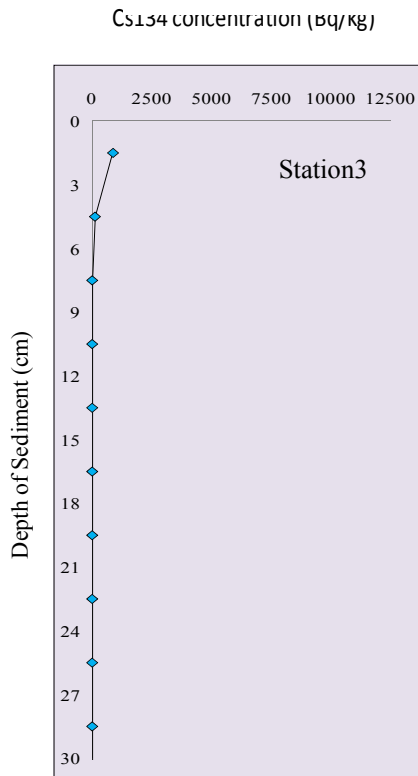


Fig.3.39(a). Vertical profile of  $^{134}\text{Cs}$  distribution in station 3

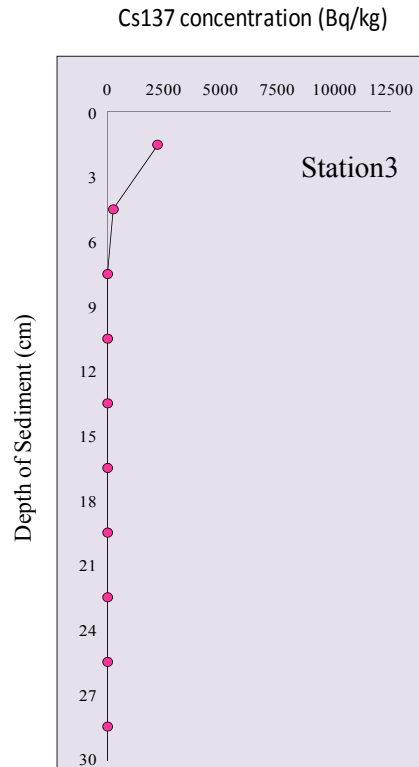


Fig.3.39(b). Vertical profile of  $^{137}\text{Cs}$  distribution in station 3

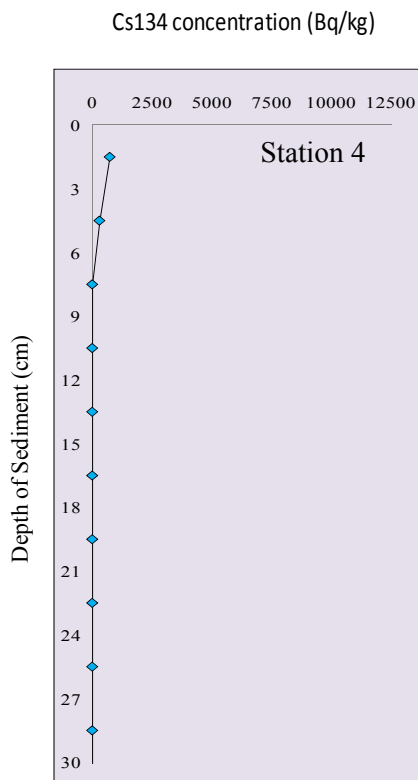


Fig.3.40 (a). Vertical profile of  $^{134}\text{Cs}$  distribution in station 4

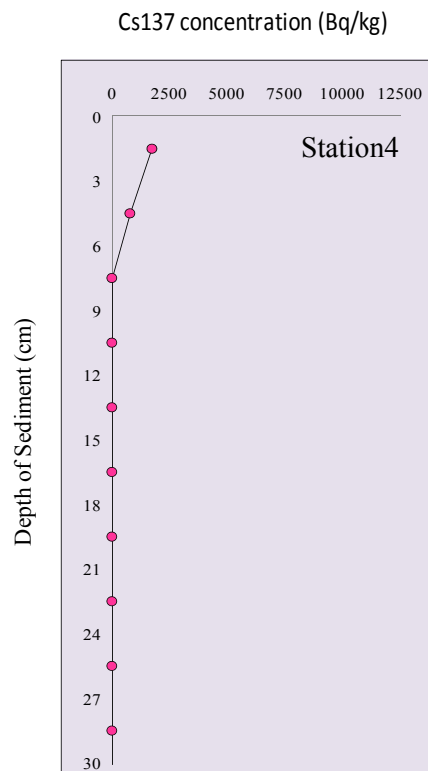


Fig.3.40(b). Vertical profile of  $^{137}\text{Cs}$  distribution in station 4

**Figure 3.41-3.42 MARCH 2013: Vertical distribution of  $^{134}\text{Cs}$  and  $^{137}\text{Cs}$  in core samples**

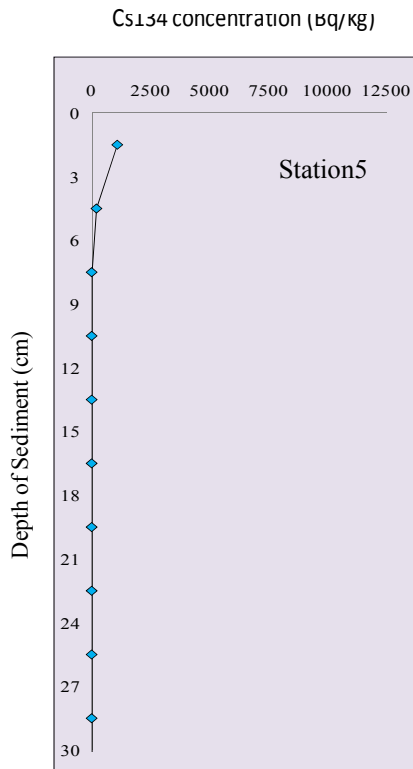


Fig.3.41(a). Vertical profile of  $^{134}\text{Cs}$  distribution in station 5

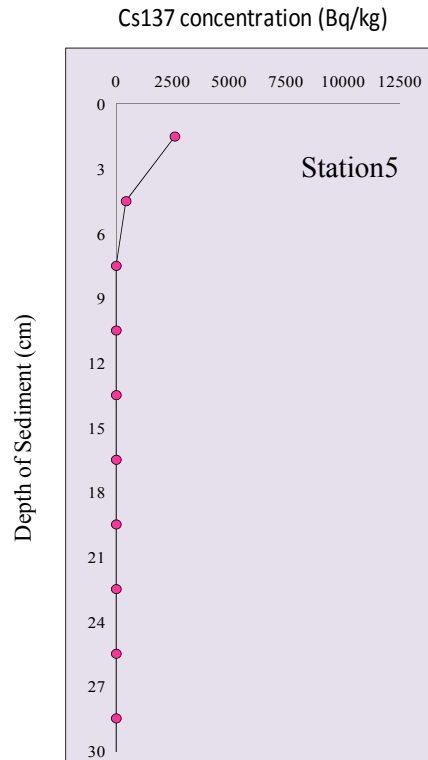


Fig.3.41(b). Vertical profile of  $^{137}\text{Cs}$  distribution in station 5

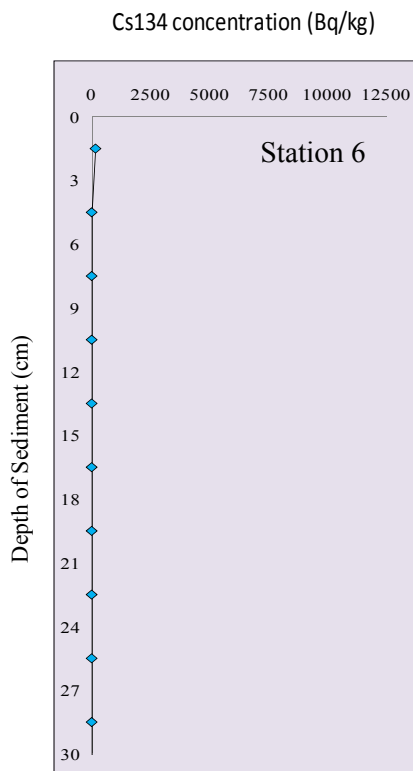


Fig.3.42 (a). Vertical profile of  $^{134}\text{Cs}$  distribution in station 6

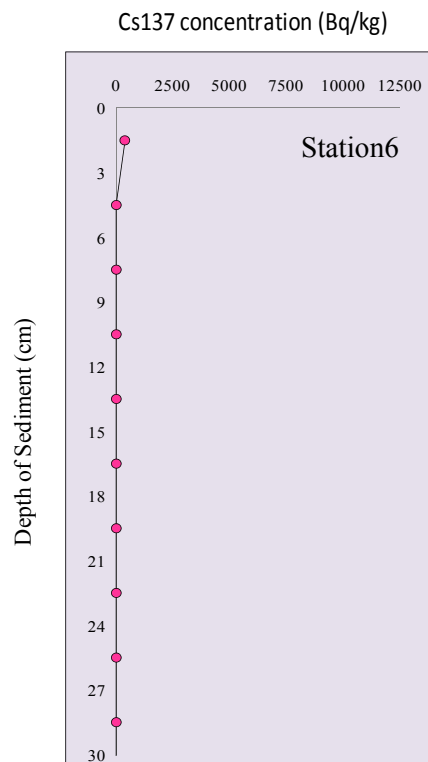


Fig.3.42(b). Vertical profile of  $^{137}\text{Cs}$  distribution in station 6

**Figure 43 MARCH 2013: Vertical distribution of  $^{134}\text{Cs}$  and  $^{137}\text{Cs}$  in core samples**

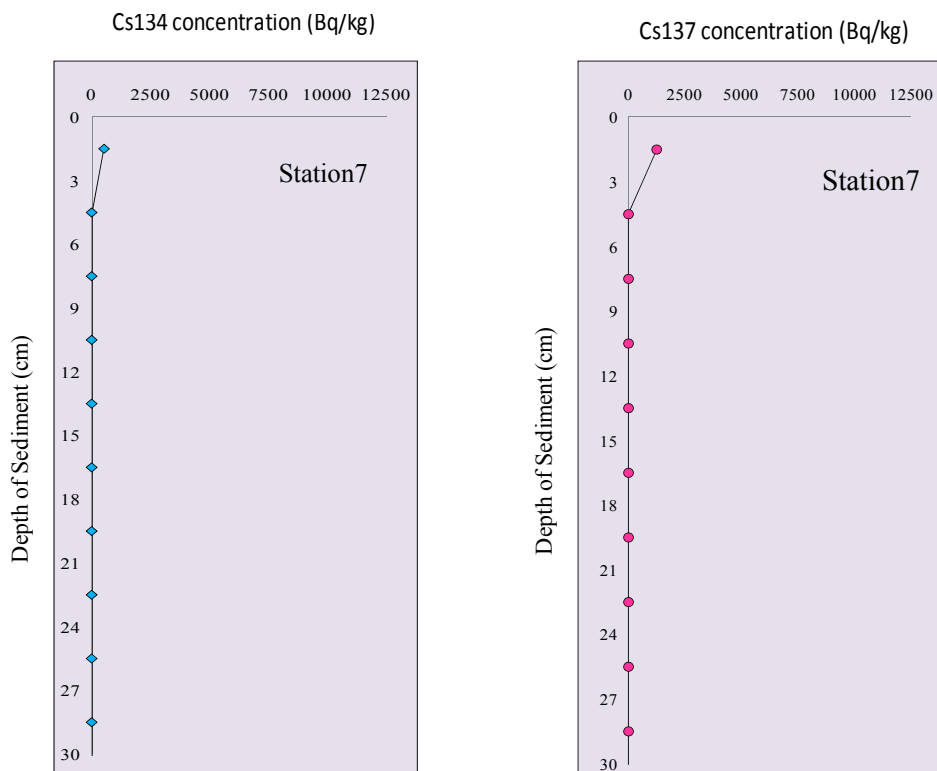


Fig.3.43(a). Vertical profile of  $^{134}\text{Cs}$  distribution in station 7

Fig.3.43(b). Vertical profile of  $^{137}\text{Cs}$  distribution in station 7



**Figure 3.44-45 MAY 2013: Vertical distribution of  $^{134}\text{Cs}$  and  $^{137}\text{Cs}$  in core samples**

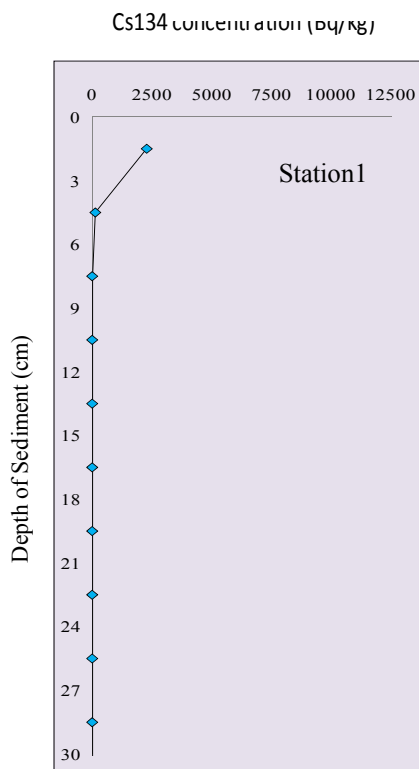


Fig.3.44(a). Vertical profile of  $^{134}\text{Cs}$  distribution in station 1

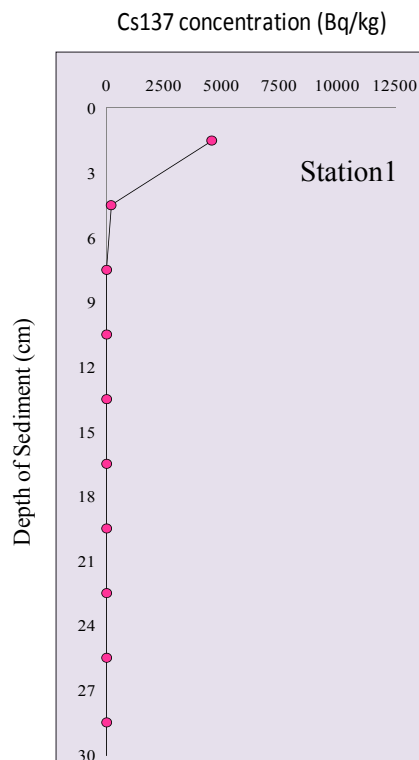


Fig.3.44(b). Vertical profile of  $^{137}\text{Cs}$  distribution in station 1

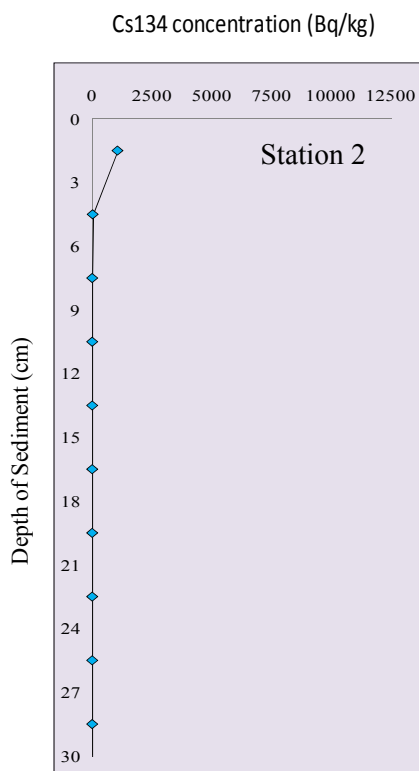


Fig.3.45 (a). Vertical profile of  $^{134}\text{Cs}$  distribution in station 2

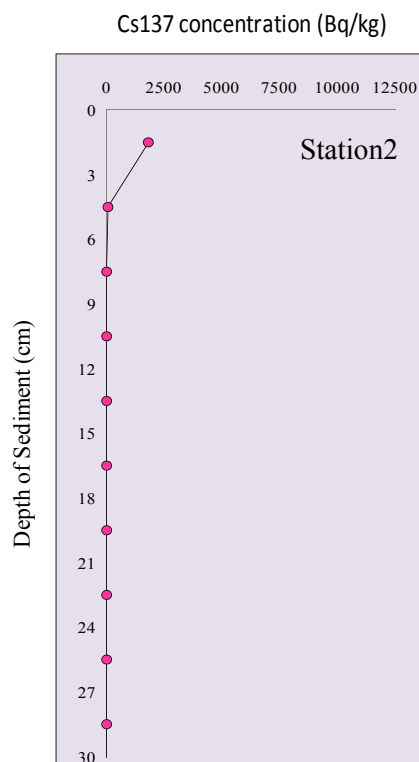


Fig.3.45(b). Vertical profile of  $^{137}\text{Cs}$  distribution in station 2

**Figure 3.46-47 MAY 2013: Vertical distribution of  $^{134}\text{Cs}$  and  $^{137}\text{Cs}$  in core samples**

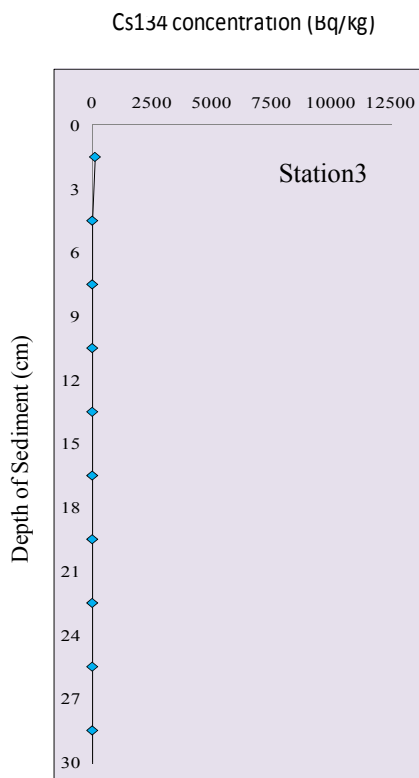


Fig.3.46(a). Vertical profile of  $^{134}\text{Cs}$  distribution in station 3

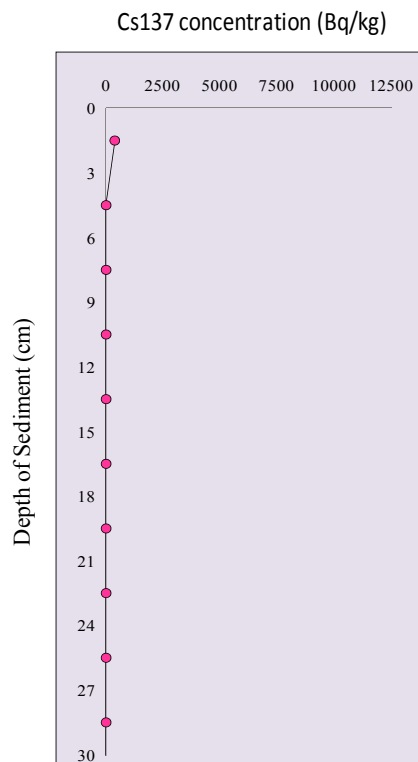


Fig.3.46(b). Vertical profile of  $^{137}\text{Cs}$  distribution in station 3

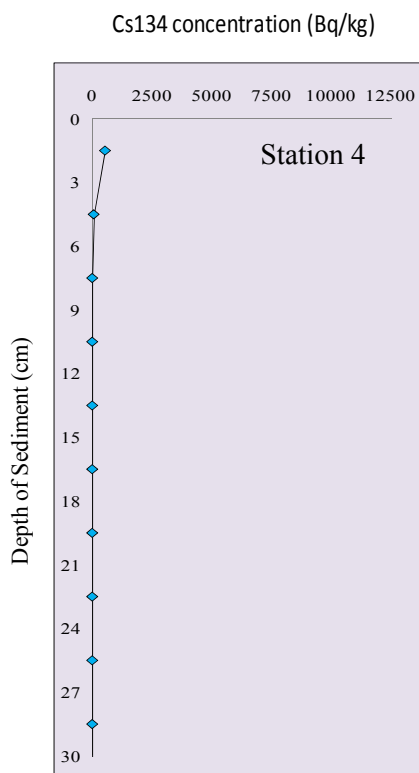


Fig.3.47 (a). Vertical profile of  $^{134}\text{Cs}$  distribution in station 4

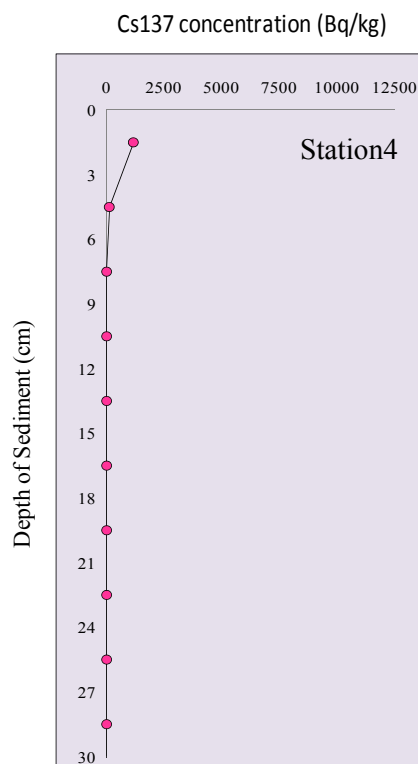


Fig.3.47(b). Vertical profile of  $^{137}\text{Cs}$  distribution in station 4

**Figure 3.48-3.49 MAY 2013: Vertical distribution of  $^{134}\text{Cs}$  and  $^{137}\text{Cs}$  in core samples**

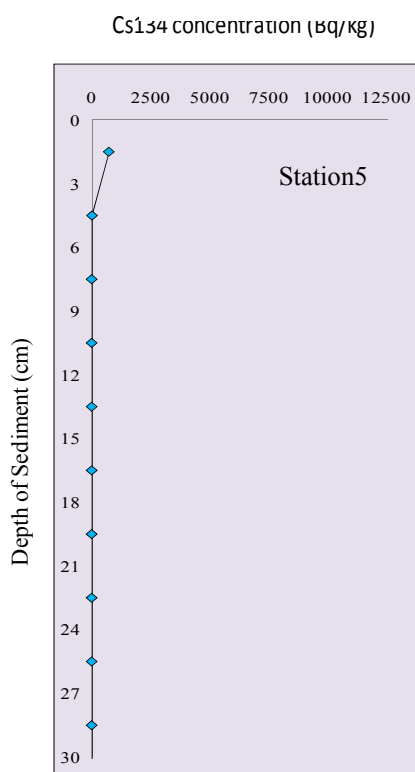


Fig.3.48(a). Vertical profile of  $^{134}\text{Cs}$  distribution in station 5

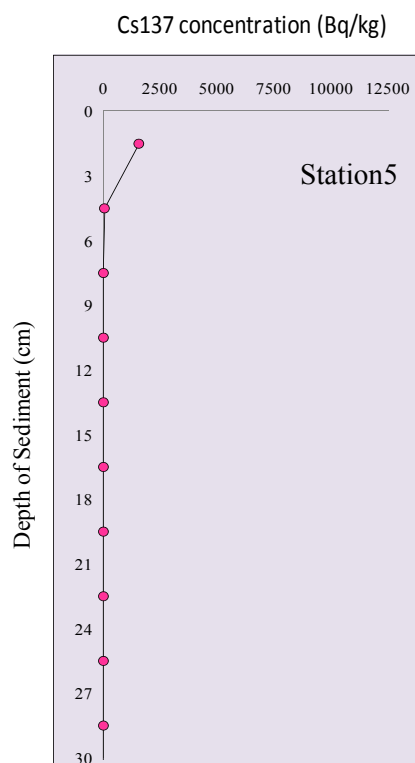


Fig.3.48(b). Vertical profile of  $^{137}\text{Cs}$  distribution in station 5

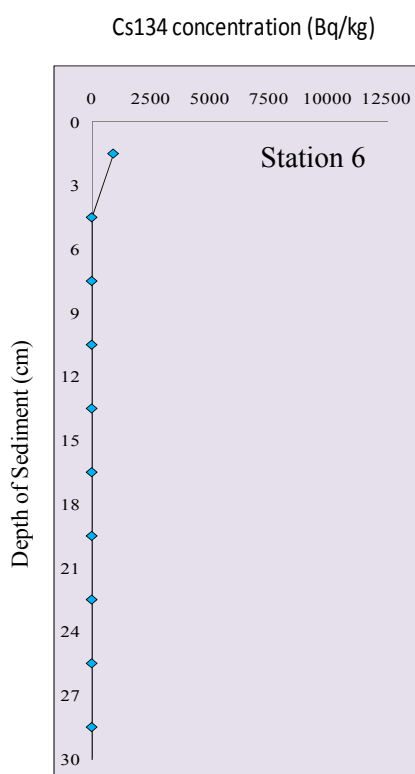


Fig.3.49 (a). Vertical profile of  $^{134}\text{Cs}$  distribution in station 6

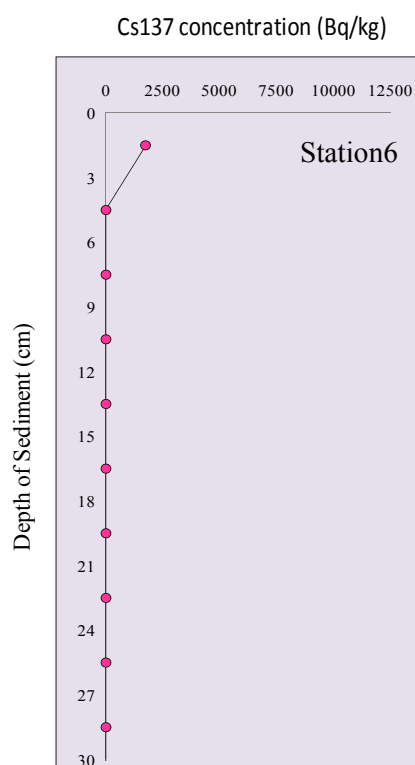


Fig.3.49(b). Vertical profile of  $^{137}\text{Cs}$  distribution in station 6

**Figure 3.50 MAY 2013: Vertical distribution of  $^{134}\text{Cs}$  and  $^{137}\text{Cs}$  in core samples**

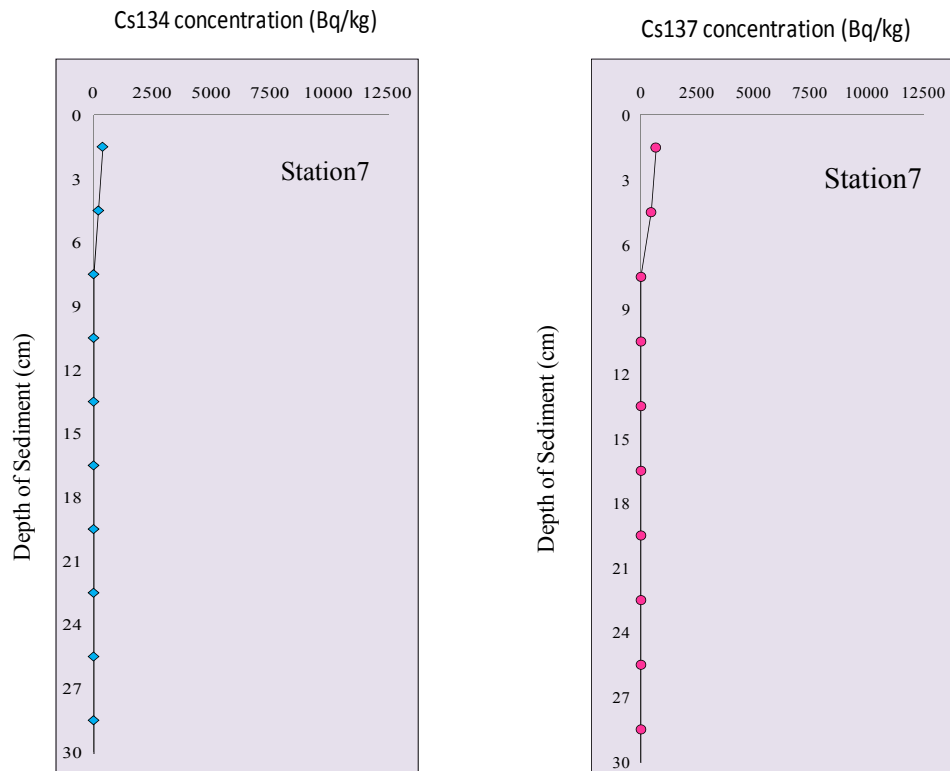
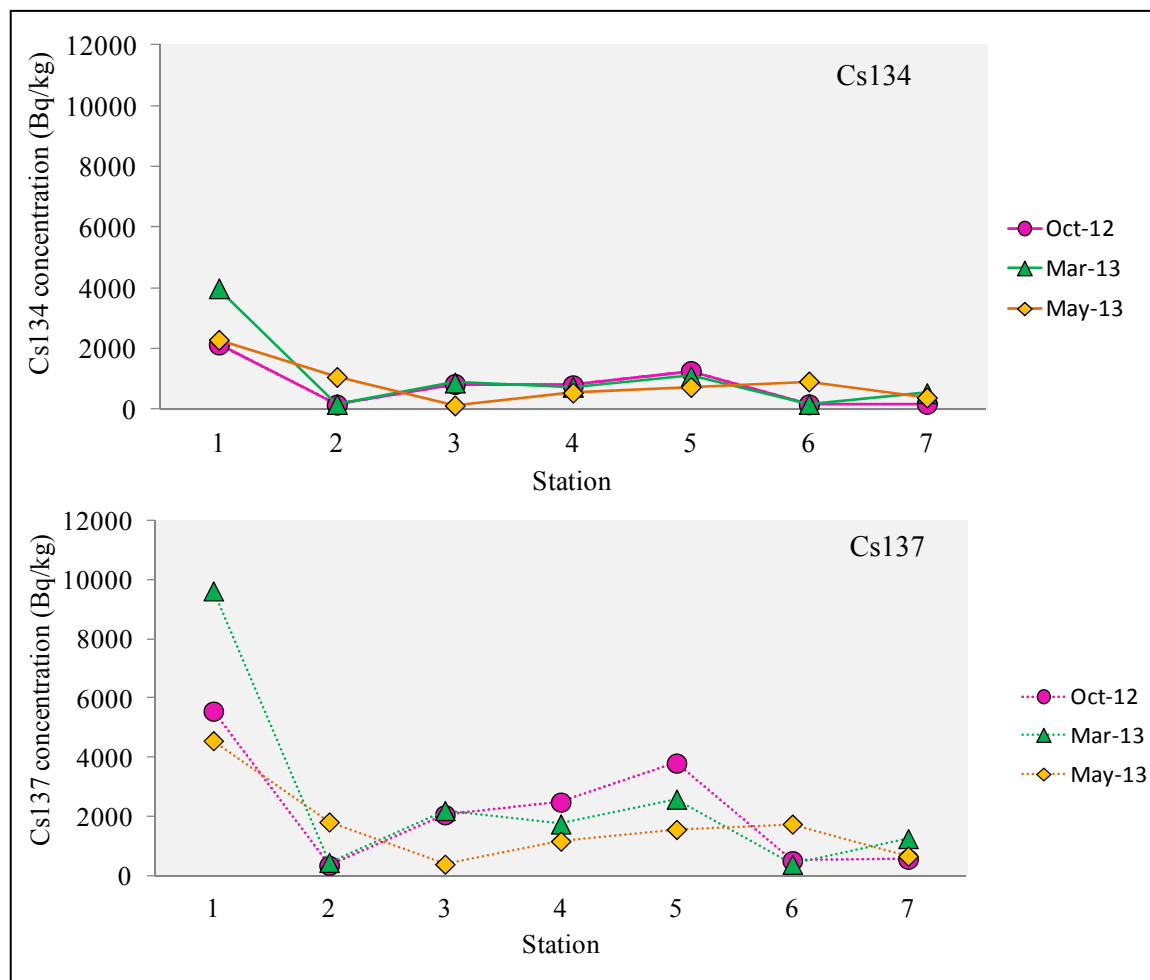


Fig.3.50(a). Vertical profile of  $^{134}\text{Cs}$  distribution in station 7

Fig.3.50 (b). Vertical profile of  $^{137}\text{Cs}$  distribution in station 7

### 3.3.2 Time variation of $^{134}\text{Cs}$ and $^{137}\text{Cs}$ in surface of sediment in Lake Teganuma



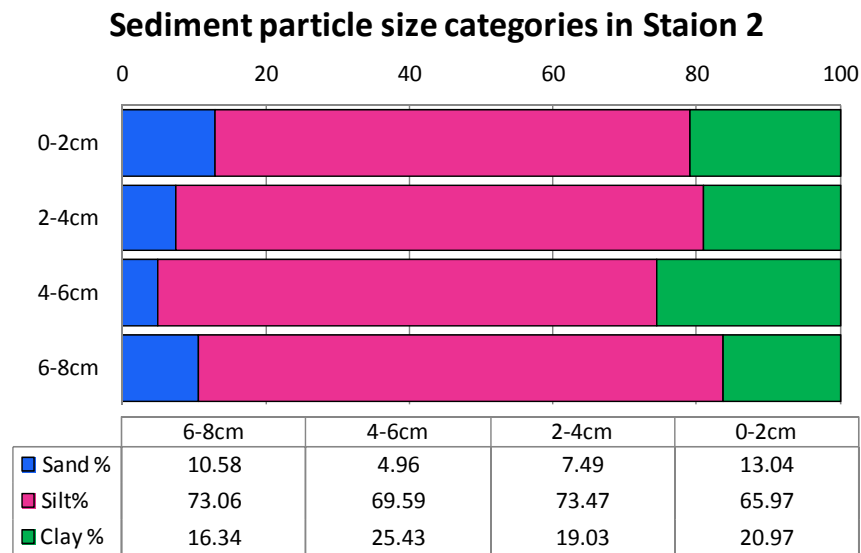
**Figure 3.51 Time variation of  $^{134}\text{Cs}$  and  $^{137}\text{Cs}$  in surface of sediment in Lake Teganuma**

Fig.3.51 This figure shown the result of time variation of radiocesium in surface sediment of 7 stations in teganuma lake , as the result on May 2013 were found the concentration almost decreased in each stations but only station 2 was increased .

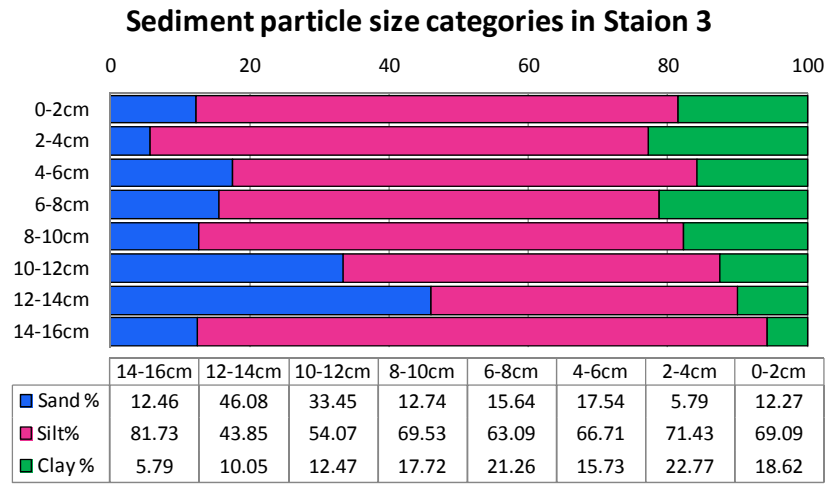
### 3.4 Particle size Analysis

#### 3.4.1 Ohori River

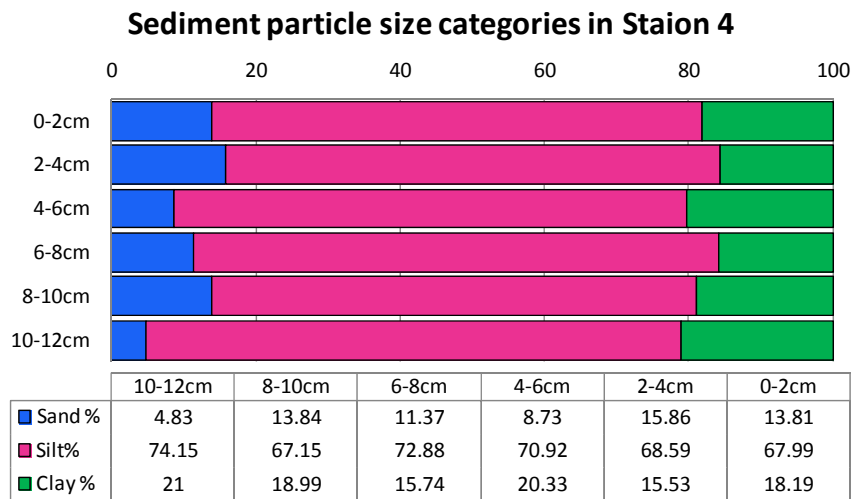
In Station 2 (Figure 3.52) the percent of sand in the layers of core sediment samples was found the minimum value reached around 5% of sediment depth 4-6 cm and highest percent 13% in the surface of depth 0-2 cm. the highest silt amount was found in the depth 2-4 cm with the value 74% . Similarly, the highest clay sediment was found in depth 4-6cm with the value 25 % . In station 1, silt was highest percent more than sand and clay with value maximum 74%.



**Figure 3.52 Sediment particle size in Station 2**

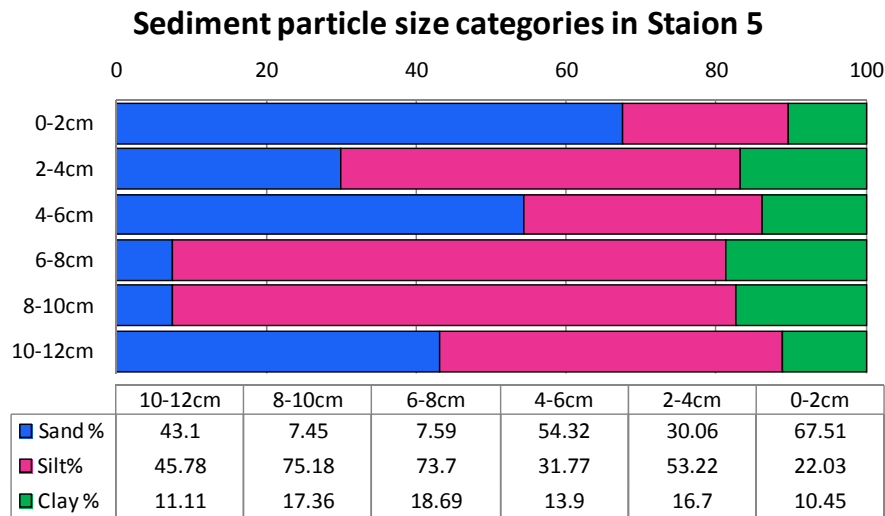


**Figure 3.53 Sediment particle size in Station 2**

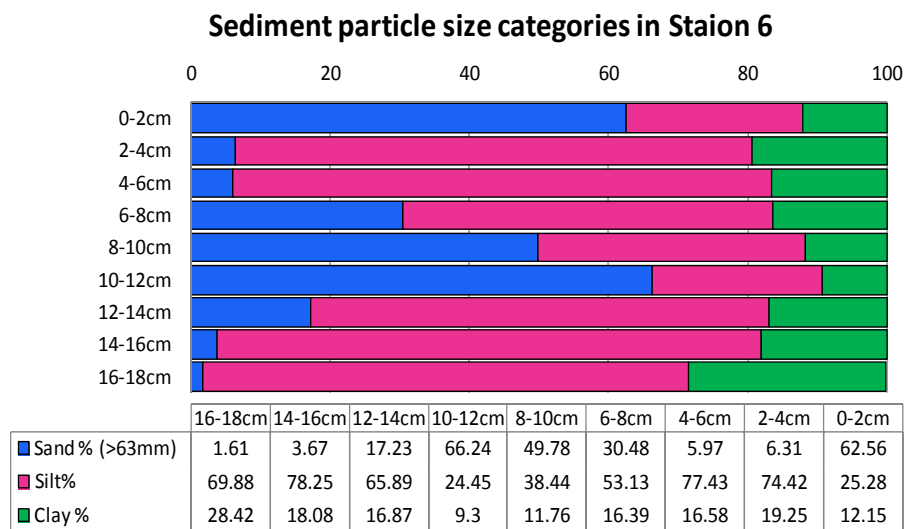


**Figure 3.54 Sediment particle size in Station 3**

In Station3 and 4 Figure 3.53-3.54, the highest percent of silt was found in the both station with value 82% in station 3 and 74% in station 4. In case of station 3 the highest percent of sand was found in layer sediment of depth 12-14cm with value 46% .



**Figure 3.55 Sediment particle size in Station 5**



**Figure 3.56 Sediment particle size in Station 6**

In Station5 and 6 Figure 3.55-3.56, the highest percent was found in both station almost silt at maximum value 75% and 78%, respectively. However, percent of sand sediment was found higher at maximum value 68% and 66%, respectively.



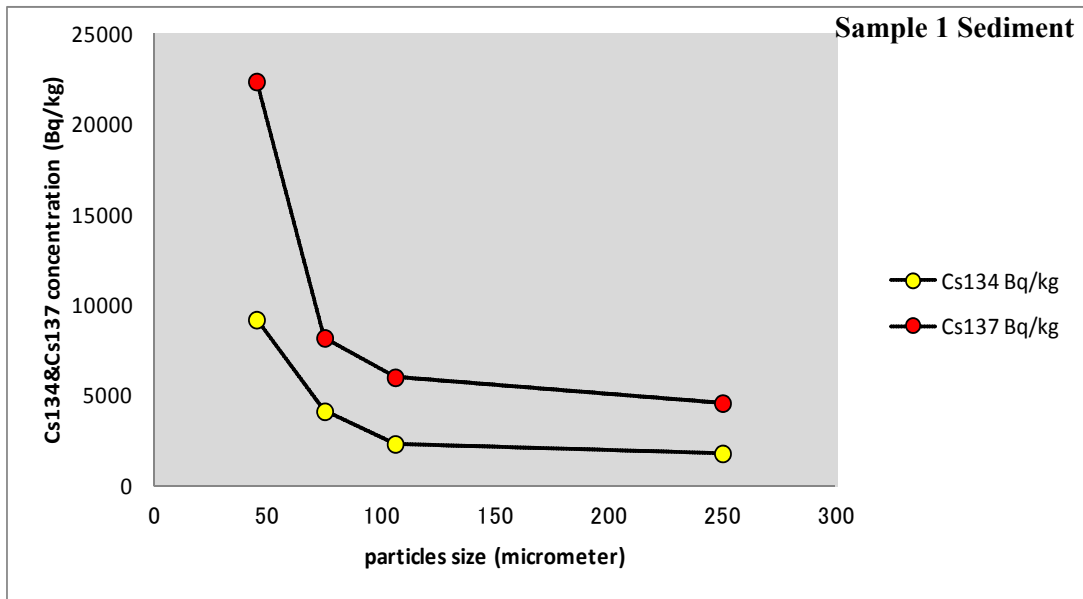
### **3.4.2 Lake Teganuma**

The Mean median value particle size (D50) in Teganuma Lake was measured in 7 stations. As the result the grain size of sediment range from 6.3 micrometer up to 199.5 micrometer, the particles size almost very fine sand and fine sand. The highest value of silt particles were found almost the same in each station range from 6.8 micrometer to 38.8 micrometer.

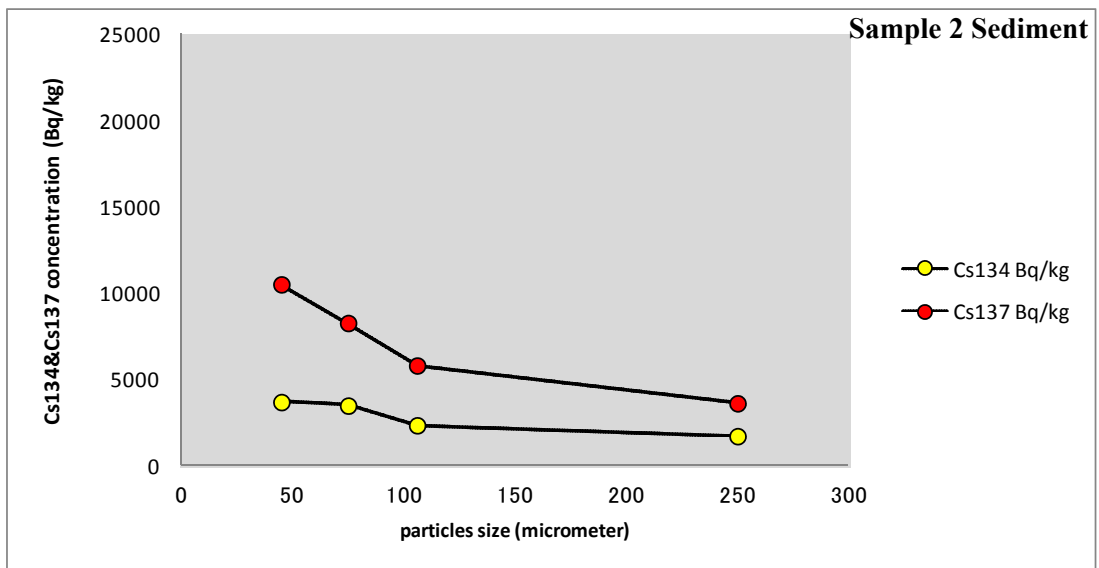
### **3.4.3 Radionuclides ( $^{134}\text{Cs}$ and $^{137}\text{Cs}$ ) in different size particle**

Figure 3.57-3.58 showed that, the radiocesium concentration for the sediment particle size  $< 45\ \mu\text{m}$  was higher than sediment particle size 75 to  $250\ \mu\text{m}$ . this result were clearly that 2 sediment samples in different station of highest radiocesium concentration was strongly absorbed with sediment particles size  $< 45\ \mu\text{m}$ .

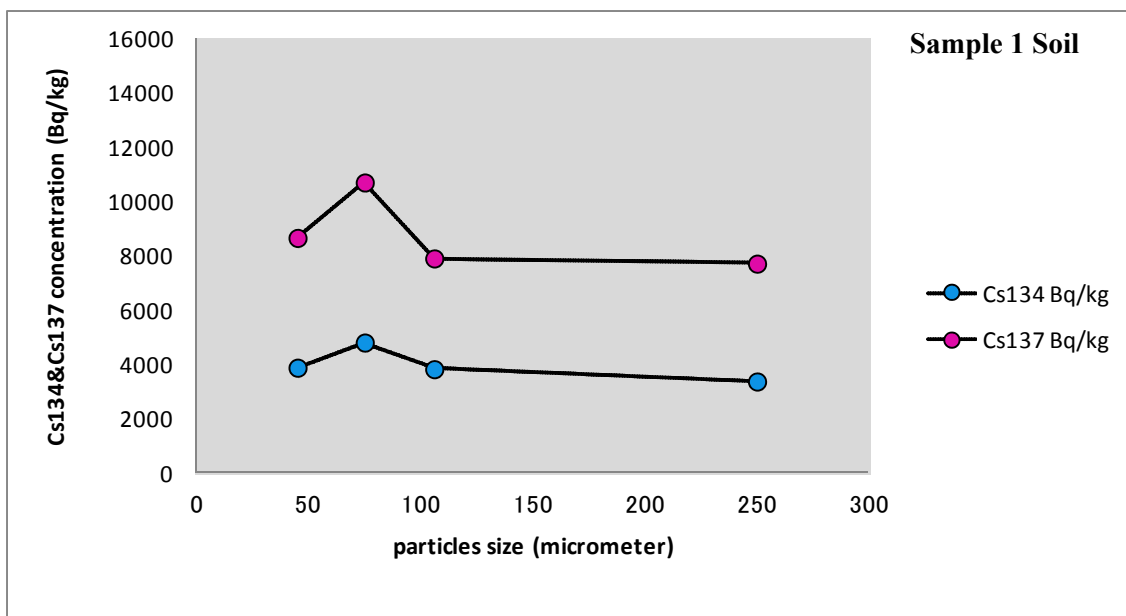
For the land soil particle size as shown in Figure 3.59-3.60 were found that, the radiocesium concentration was high in the particle size range from  $75\ \mu\text{m}$  to  $106\ \mu\text{m}$ , respectively. However, soil particle size  $< 45\ \mu\text{m}$  was not strongly absorbed with soil particles size as shown clearly the same in 2 soil samples.



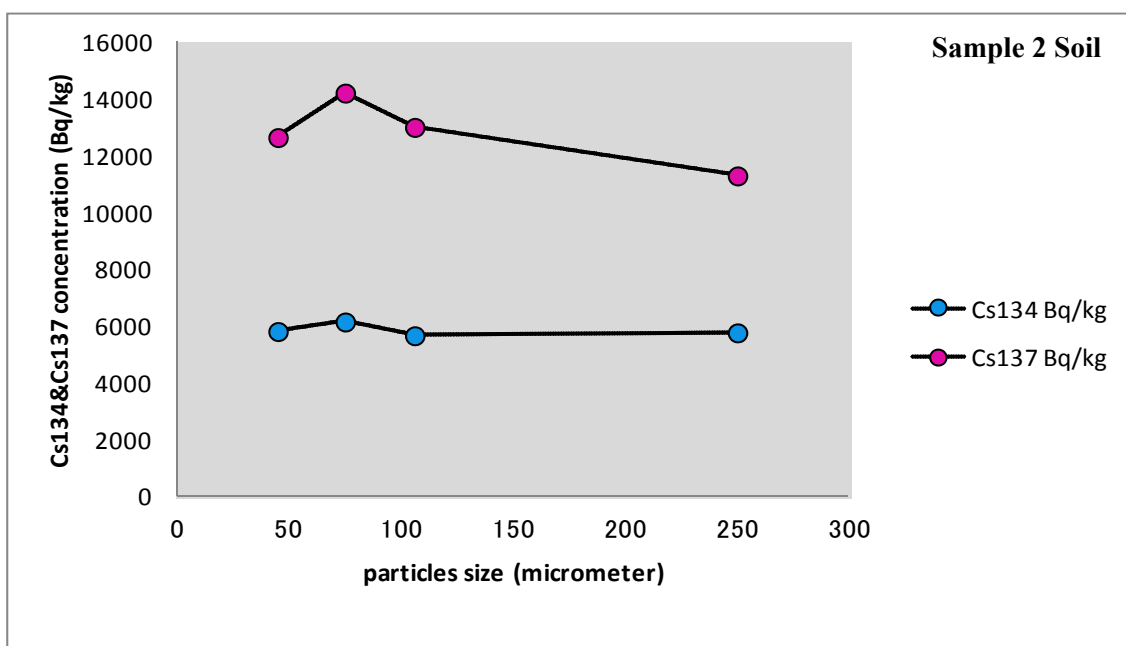
**Figure 3.57** The concentration of radiocesium with different size of particle in the sediment of sample 1



**Figure 3.58** The concentration of radiocesium with different size of particle in the sediment of sample 2



**Figure 3.59** The concentration of radiocesium with different size of particle in the land soil of sample 1



**Figure 3.60** The concentration of radiocesium with different size of particle in the land soil of sample 2

### 3.5 Estimated Total mass of sediment and radiocesium in Ohori River and Teganuma Lake

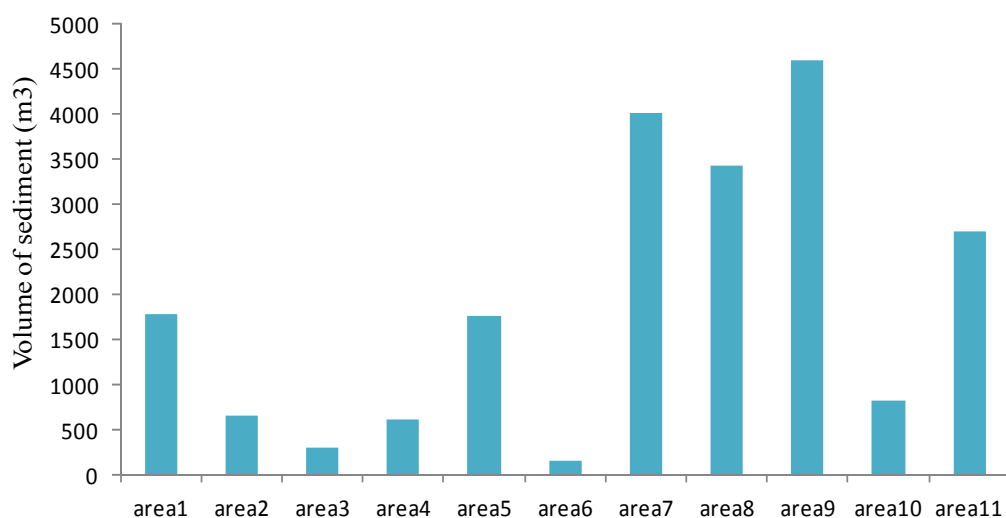
Base on the result of radiocesium distribution in the core samples, depth of radiocesium contaminated in sediment can used to calculate the total volume of sediment contaminated with radiocesium and the concentration of radiocesium can used to calculate the total mass of radiocesium accumulated in Ohori river and Lake Teganuma. The results of calculation were shown in each section as follows.

#### 3.6.1 Total volume of sediment contaminated with radiocesium ( $\text{m}^3$ ) in Ohori River

Table 3.1 and Figure 3.61 showed the volume of sediment contaminated with radiocesium in 11 point of Ohori River and was high in station 7 to station9 and total volume of sediment was  $2.08 \times 10^4 \text{ m}^3$  in 2012.

**Table 3.1 Volume of sediment contaminated with radiocesium in 11 points of Ohori River 2012**

Point	Area ( $\text{m}^2$ )	depth (m) 2012	Volume2012( $\text{m}^3$ )
area1	25413	0.07	$1.77 \times 10^3$
area2	9556	0.07	$6.69 \times 10^2$
area3	4213	0.07	$2.95 \times 10^2$
area4	4807	0.13	$6.25 \times 10^2$
area5	11819	0.15	$1.77 \times 10^3$
area6	16321	0.01	$1.63 \times 10^2$
area7	26821	0.15	$4.02 \times 10^3$
area8	22823	0.15	$3.42 \times 10^3$
area9	15891	0.29	$4.61 \times 10^3$
area10	5440	0.15	$8.16 \times 10^2$
area11	14270	0.19	$2.71 \times 10^3$

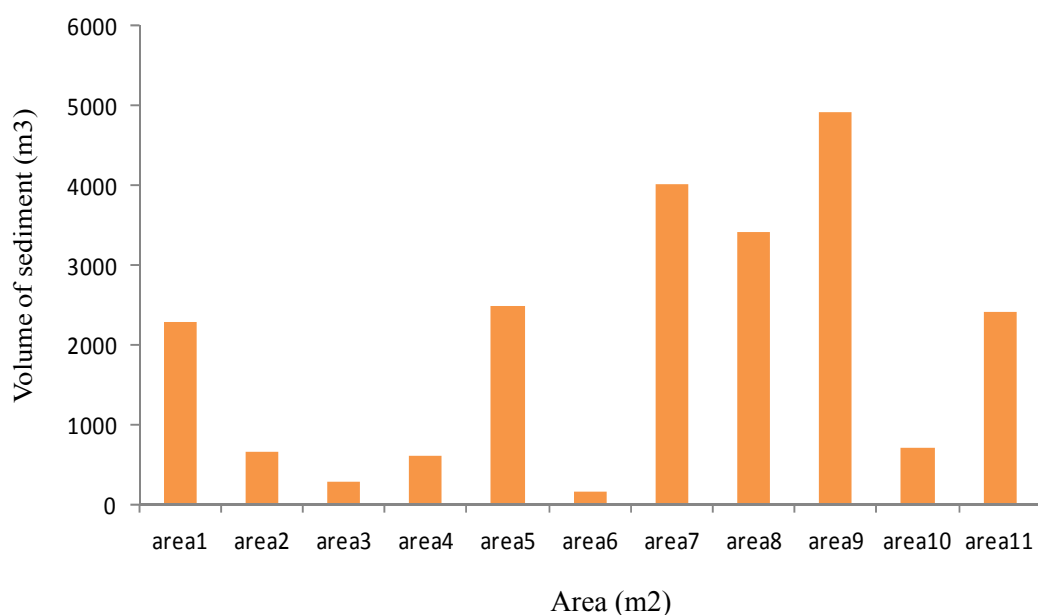


**Figure 3.61 Volume of sediment contaminated with radiocesium in 11 points of Ohori River 2012**

Table 3.2 and figure 3.62 showed the result of the volume of sediment contaminated with radiocesium in 2013 as the value  $2.20 \times 10^4 \text{ m}^3$  and the volume still high in station 7 to station 9.

**Table 3.2 Volume of sediment contaminated with radiocesium in 11 points of Ohori River 2013**

Point	Area (m2)	depth(m) 2013	Volume 2013(m3)
area1	25413	0.09	$2.29 \times 10^3$
area2	9556	0.07	$6.69 \times 10^2$
area3	4213	0.07	$2.95 \times 10^2$
area4	4807	0.13	$6.25 \times 10^2$
area5	11819	0.21	$2.48 \times 10^3$
area6	16321	0.01	$1.63 \times 10^2$
area7	26821	0.15	$4.02 \times 10^3$
area8	22823	0.15	$3.42 \times 10^3$
area9	15891	0.31	$4.93 \times 10^3$
area10	5440	0.13	$7.07 \times 10^2$
area11	14270	0.17	$2.43 \times 10^3$



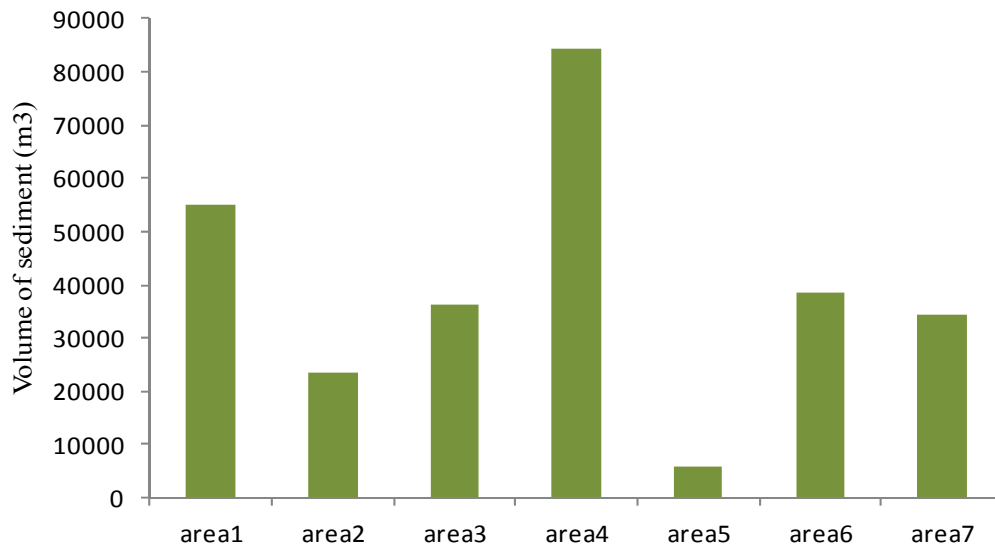
**Figure 3.62** Volume of sediment contaminated with radiocesium in 11 points of Ohori River 2013

### 3.6.1 Total volume of sediment contaminated with radiocesium (m³) in Lake Teganuma

Table 3.3 and Figure 3.63 shown the volume of sediment contaminated with radiocesium in 7 point of Lake Teganuma was highest in station 4 and total volume of sediment was  $2.78 \times 10^5 \text{ m}^3$  in October 2012.

**Table 3.3** Volume of sediment contaminated with radiocesium in 7 points of Lake Teganuma October 2012

Point	Area (m <sup>2</sup> )	depth (m) 2012	Volume October 2012(m3)
area1	183668	0.3	$5.51 \times 10^4$
area2	390510	0.06	$2.34 \times 10^4$
area3	603474	0.06	$3.62 \times 10^4$
area4	935104	0.09	$8.42 \times 10^4$
area5	63786	0.09	$5.74 \times 10^3$
area6	1288500	0.03	$4 \times 10^4$
area7	1149400	0.03	$3 \times 10^4$

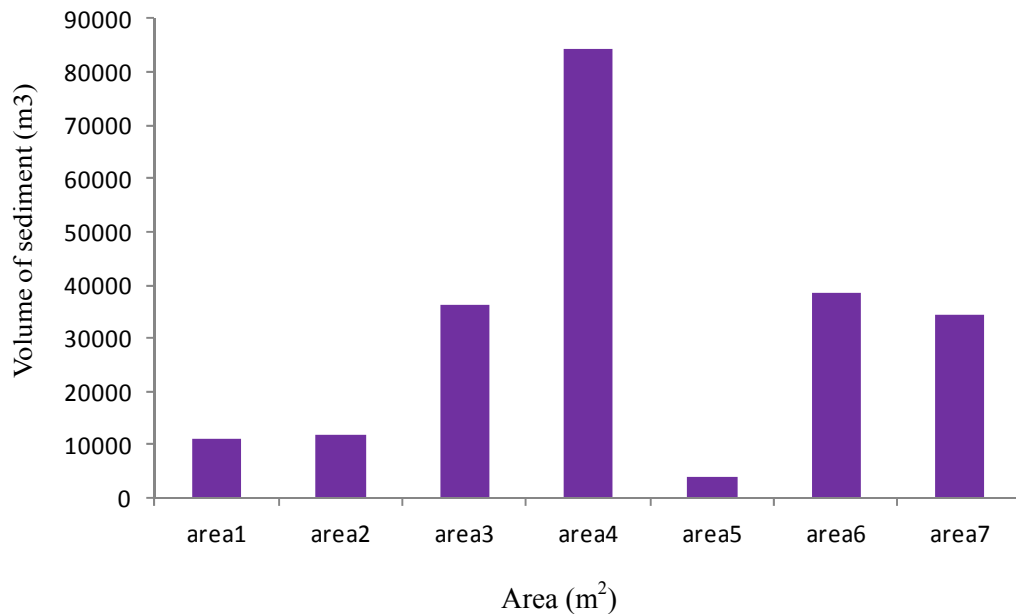


**Figure 3.63** Volume of sediment contaminated with radiocesium in 7 points of Lake Teganuma October 2012

Table 3.4 and figure 3.64 shown the volume of sediment contaminated with radiocesium on March 2013 and total volume of sediment was  $2.20 \times 10^5 \text{ m}^3$ . The highest of volume was found in station 4 as the same result of October 2012.

**Table3.4** Volume of sediment contaminated with radiocesium in 7 points of Lake Teganuma March 2013

Point	Area (m <sup>2</sup> )	depth(m) 2013	Volume March 2013 (m3)
area1	183668	0.06	$1.10 \times 10^4$
area2	390510	0.03	$1.17 \times 10^4$
area3	603474	0.06	$3.62 \times 10^4$
area4	935104	0.09	$8.42 \times 10^4$
area5	63786	0.06	$3.82 \times 10^3$
area6	1288500	0.03	$3.87 \times 10^4$
area7	1149400	0.03	$3.45 \times 10^4$



**Figure 3.64 Volume of sediment contaminated with radiocesium in 7 points of Lake Teganuma March 2013**

### **3.6.2 Total mass of sediment contaminated with radiocesium (Ton) in Ohori River and Lake Teganuma**

Base on the result of total volume of sediment, unite of m<sup>3</sup> converted to Ton (multiply of 1.6) and total mass of sediment contaminated with radiocesium were calculated as the result of total mass of sediment in October 2012, Ohori river and Lake Teganuma were  $3.34 \times 10^4$  Ton,  $4.44 \times 10^5$  Ton. In March 2013 were  $3.52 \times 10^4$  Ton,  $3.52 \times 10^5$  Ton, respectively. Therefore , Compare the total mass of sediment contaminated with radiocesium in October 2012 and March 2013, in Ohori river the total mass was increasing 5% but in Lake Teganuma was decreasing 23%, respectively.



### 3.6.2 Total amount of Radiocesium (Bq)

Total amount of radiocesium were calculated by using total mass of sediment (kg) per layer of sediment contaminated radiocesium and multiply of concentration of ( $^{134}\text{Cs}+^{137}\text{Cs}$ ). As the result of total amount radiocesium (Bq) in Ohori river and Lake Teganuma were  $2.19 \times 10^{11}$  Bq,  $7.41 \times 10^{11}$  Bq in October 2012, respectively. However, March 2013 the total amount of radiocesium was calculated in Lake Teganuma as value  $6.13 \times 10^{11}$  Bq and in Ohori river is  $1.83 \times 10^{11}$  Bq. total amount of radiocesium almost decreasing gradually in Ohori river 16% and lake Teganuma 17%, respectively because the half life of  $^{134}\text{Cs}$  only 2 year.

## **CHAPTER 4: DISCUSSIONS**

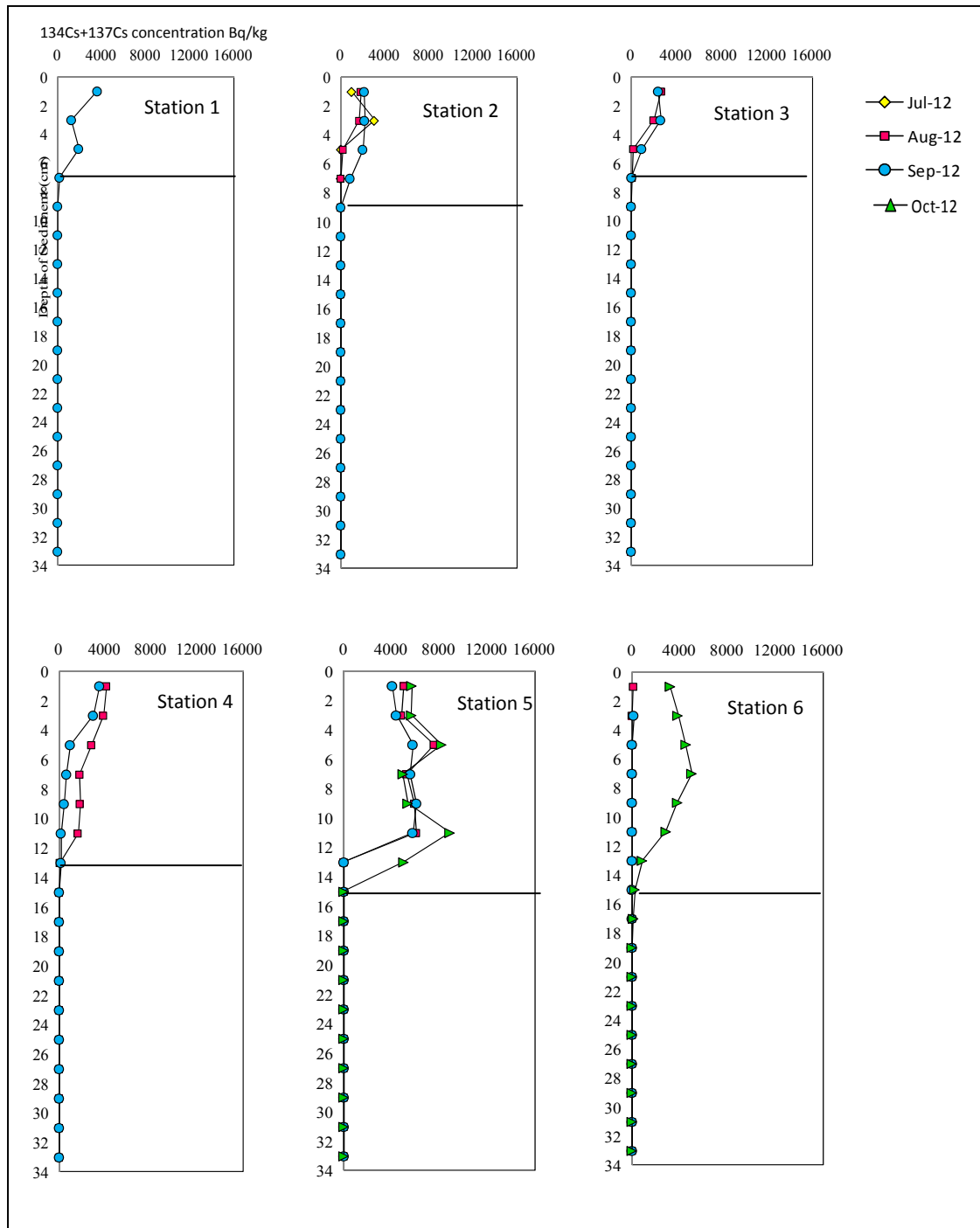
### **4.1 Cesium radionuclids distribution in Ohori River and Teganuma Lake**

#### **4.1.1 Vertical variation distribution of radiocesium in Ohori river ( July – December 2012)**

Distribution of vertical variation in upper part, middle part and lower part of Ohori River is discussed. The depth of radiocesium concentration in the sediment layers of each station is considered as the parameter to calculate the total volume and mass of sediment accumulated in the bottom of river.

The depth profile of  $^{134}\text{Cs}$  and  $^{137}\text{Cs}$  from core collected on July to October 2012 in middle part of river, which clearly indicates that  $^{134}\text{Cs}$  and  $^{137}\text{Cs}$  has started to accumulated in bottom of sediment because in station 1, 2 and 3, the depth is almost same ranging from 4cm to 8cm. In the middle part of river, thickness accumulated  $^{134}\text{Cs}$  and  $^{137}\text{Cs}$  occurs in station 4 and 5 with the depth of 14cm-16cm. However, in station 5, two peaks are shown in the depth from 4cm and 12cm. In Figure 4.1 as the depth of sediment results were clearly a maximum at 16 cm depth of pollution in middle part of river related to the fallout of radiocesium from Fukushima accident on march 2011 confirmed by the  $^{134}\text{Cs} / ^{137}\text{Cs}$  core profile ratio.

For discussion of this result the question: why in station 4 and 5 and 6 were found the high deposited in the depth of sediment ranging from 14 cm to 16 cm? in this result might be the reason of water velocity should be consider. There for, the peak in station 5 were found 2 peaks and assume on this peak occurred after Fukushima daichi power plant accident in 2011.



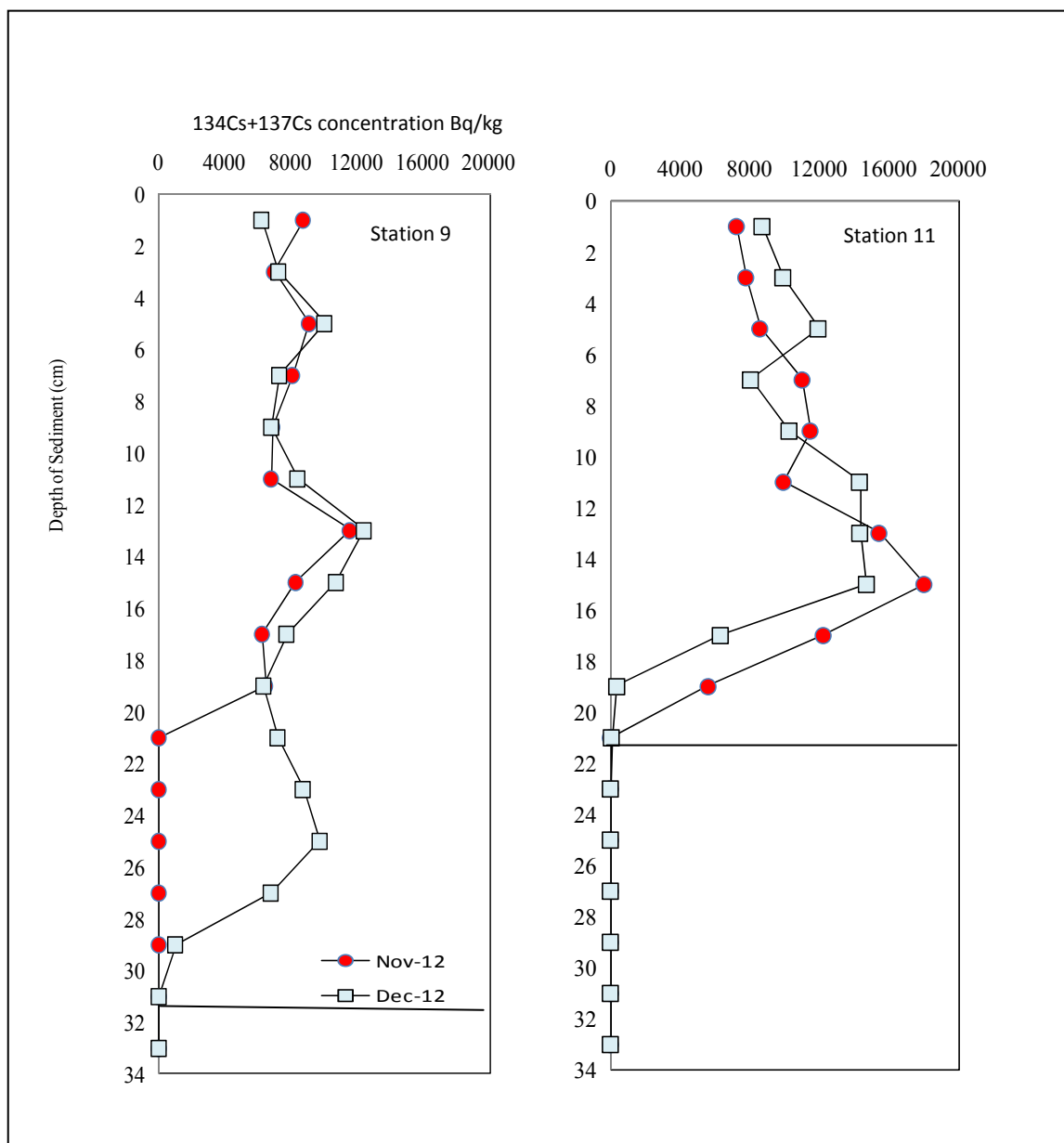
**Figure 4.1 Vertical variation distribution of radiocesium ( $^{134}\text{Cs}+^{137}\text{Cs}$ ) in upper part and middle part of river on July – October 2012.**

On November and December 2012, core samples were collected in the lower part of the river at 5 stations (station 7 to station 11) is shown that the depth of cesium polluted in station 7, 8, and 10 were around 14cm-16cm but has rapidly increased at around 28cm-30cm and 20cm-22cm in stations 9 and 11, respectively. Moreover, the concentrations of radiocesium ( $^{134}\text{Cs}+^{137}\text{Cs}$ ) on December were highest in the depth of 12cm -14cm with value  $1.16 \times 10^4$  Bq/kg in station 9 and 14cm-16cm with value  $1.80 \times 10^4$  Bq/kg in station 11. It clearly showed that there is highest accumulated of the radionuclide in the lower part of Ohori river (river mouth near the lake) Figure 4.2 and the radiocesium was accumulated into river mouth in 2012 .

For discussion on this result: the 3 peaks were found in station 9 with the depth 4-6cm , 12-14cm and 24-26cm and 2 peak was found in station 11 with the depth 4-6cm and 14-16cm, respectively. There are at least two major radionuclide input events in both Station 9 and 11 causing the radionuclide concentrations to peak at two different depths at approximately 2 – 8 cm and 11 – 17 cm. The result of these peaks in the lower layer of sediment indicates downward advection or mixing of cesium in the core sample. In addition, during this time 2 or 3 rain event or storm occurred in this area.

The sediment where the peaks occur was mostly composed of silt and clay with average sizes ranging from 12  $\mu\text{m}$  to 25  $\mu\text{m}$ . The silt and clay have high retention capacity and therefore these sediment types were able to store and absorb more radionuclide, causing the radionuclide concentrations to peak.

In order to find out the input event that are causing the peaks in radionuclide concentrations along the river, it is suggested that the sediment dating should be carried out to find what kind of natural or artificial input events (e.g. atmospheric, erosion or manmade) can be linked to it.



**Figure 4.2 Vertical variation distribution of radiocesium ( $^{134}\text{Cs}+^{137}\text{Cs}$ ) in lower part of river on November – December 2012.**

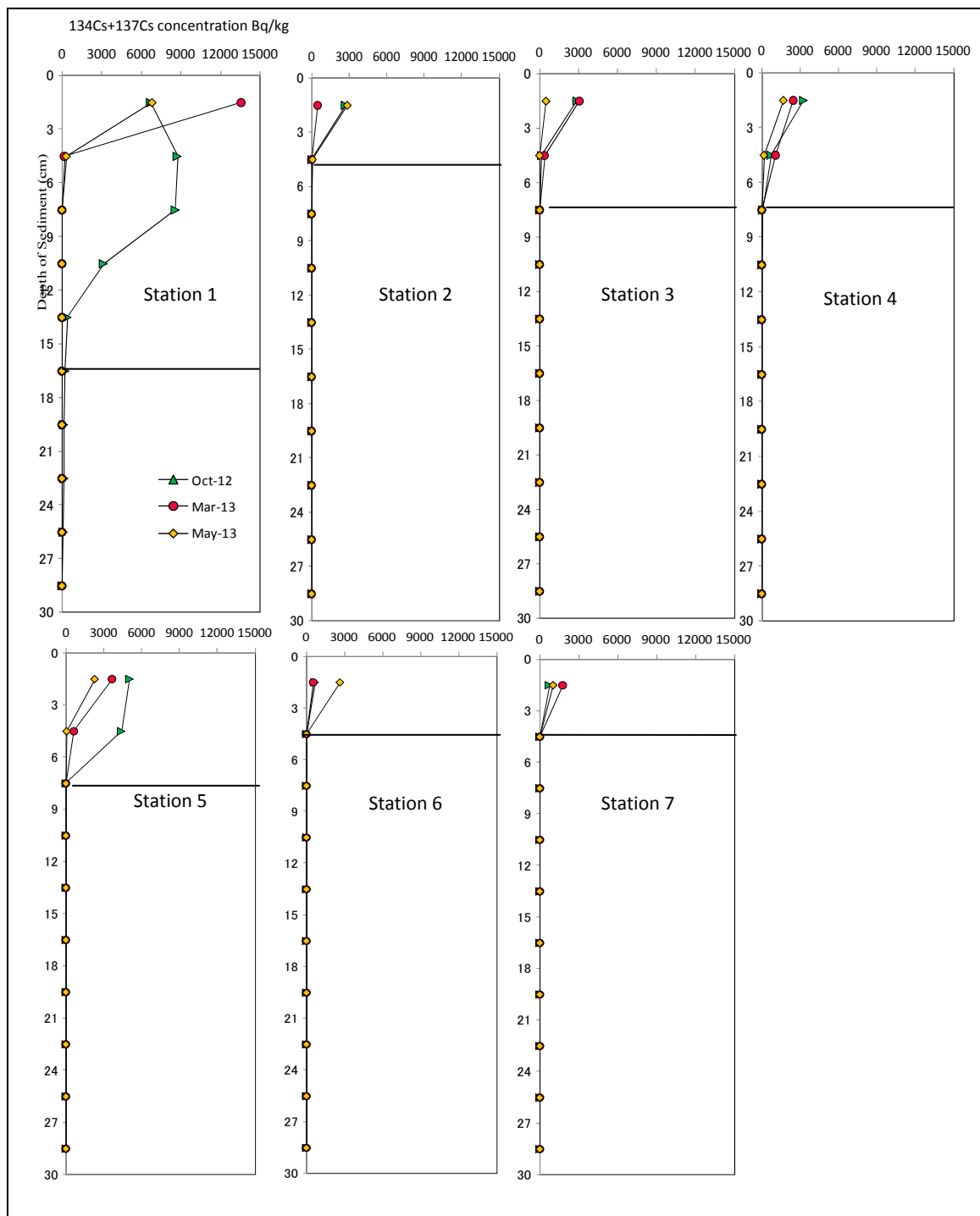
#### **4.1.1 Vertical variation distribution of radiocesium in Lake Teganuma**

Samples from Lake Teganuma were collected on three occasions in October 2012, March 2013 and May 2013.  $^{134}\text{Cs}$  and  $^{137}\text{Cs}$  concentrations were found to be highest at the depth of 15 – 18 cm in Station 1, which is located closest to the Ohori river mouth, during the October 2012 sampling. Radionuclides released after the Fukushima Daiichi Nuclear Power Plant disaster on March 2011 could have been concentrated at this part of the lake via direct inflow from the Ohori River and erosion, as shown by the higher concentrations of  $^{134}\text{Cs}$  and  $^{137}\text{Cs}$  at this depth (Figure 4.3).

However, in the middle and lower part of the lake, radiocesium peaks were only found at sediments that are close to the surface. Radiocesium peaks were detected at the depth of 6 cm at Station 2 and 3, 9 cm at Station 4 and 5 and 3 cm at Station 6 and 7. This showed that the radiocesium concentration forms a depth gradient along the lake, with the first event of radiocesium deposition at station that is closest to the Ohori River (deepest depth), followed by the middle part of the lake and the latest deposition at shallower depths in stations that are the furthest away from the river mouth.

Compared to data from the October 2012 sampling, the depth of which the radiocesium concentrations peaked has reduced during the March 2013 sampling. At Station 1, the depth in which the radiocesium can be found has reduced from 18cm to 6cm. In May, the  $^{134}\text{Cs}$  and  $^{137}\text{Cs}$  concentrations have decreased in the surface sediments in Station 1. However, Station 2 which showed a slight increment in the radionuclide concentration at the surface sediment. The depth at which the radionuclide peaked remains the same at stations located at the middle and the end of the lake, with a slight increment of radionuclide concentrations at surface sediments.

There were a few factors which could contribute to the decreased radiocesium concentrations along the river during the 6 month's period between the October 2012 and March 2013 samplings. Firstly, three high rainfall events were recorded during this 6 month's period. Secondly, the water depth especially in Station 1 is quite shallow and this could promote mixing and flow of radionuclides downstream. Lastly, the radionuclide flux from the source has reduced.



**Figure 4.3 Vertical variation distribution of radiocesium ( $^{134}\text{Cs}+^{137}\text{Cs}$ ) in Lake Teganuma in October 2012 , March and May 2013.**

## 4.2 Radiocesium concentration in different Particles size from the land soil and sediment in Ohori basin and river

Based on the results of the experiment, two stations with the highest Cs concentration were selected both for the land area and the surface river sediment, with one sample being collected per station. The result of sediment soil in river were clearly demonstrates that the adsorption of radiocesium are closely related to the sediment size  $< 45 \mu\text{m}$  is mean finer sand (silt plus clay). In case of land soil particles on the land, adsorption of radiocesium are closely the particles size range from  $50\text{-}106 \mu\text{m}$  was greater size than sediment particles in river. However, adsorption of radiocesium are strongly with particles size range from  $<106 \mu\text{m}$  and confirmed by the results obtained from the trend in sediment and land soil samples which highest contaminated radiocesium in different samples point location.

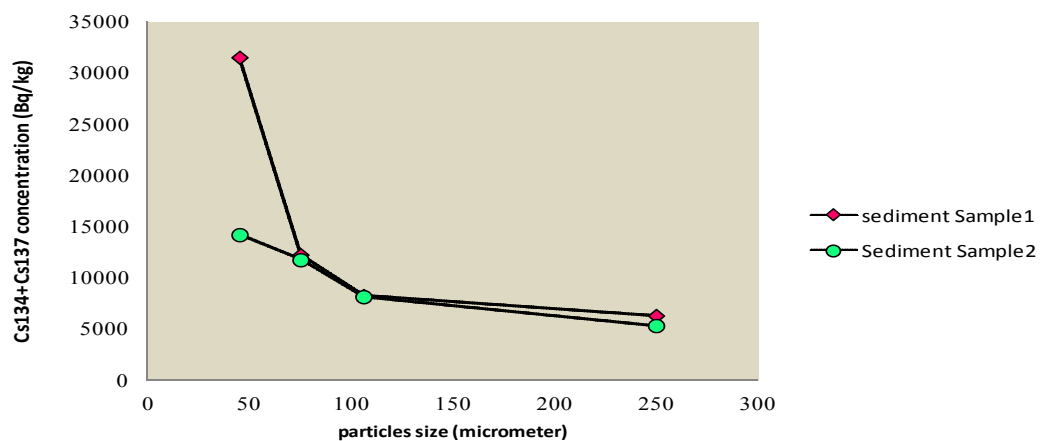


Figure 4.4 Concentrations of Cs134+Cs137 of sediment samples in different size particles

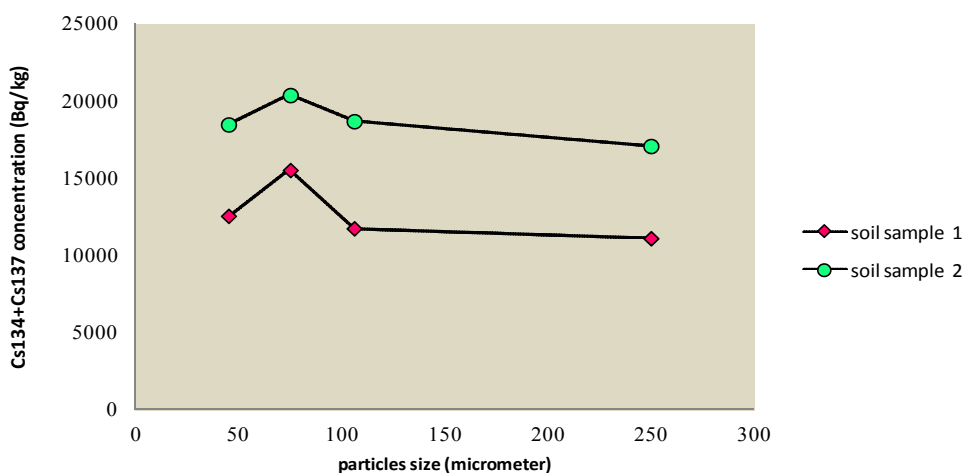


Figure 4.5 Concentrations of Cs134+Cs137 of soil samples in different size particles



Moreover, the question is why the particles size adsorption of radiocesium in the soil land greater than the sediment in the river?

In the order to discussion in this reason we are consumed that the measurement process or error occurred during experiment. More samples and measurement time needed to confirm on this result.

#### 4.3 Estimation of total mass of sediment and total amount of radiocesium in Ohori River and Lake Teganuma

Comparison of total mass of sediment contaminated with radiocesium in Ohori River based on the measurement results between October 2012 and March 2013, clearly shown that the total mass of sediment increasing in 2013. However, the total amount of radiocesium (Bq) tended to decrease gradually since half life of  $^{134}\text{Cs}$  is 2 years Table 4.1.

**Table 4.10 Total mass of sediment and total amount of radiocesium comparison in Ohori River (2012-2013)**

<b>Ohori River</b>			
Time	Volume (m <sup>3</sup> )	Total Mass (Ton)	Cs <sup>134</sup> +Cs <sup>137</sup> (Bq)
Oct-12	2.08x10 <sup>4</sup>	3.34x10 <sup>4</sup>	2.19x10 <sup>11</sup>
Mar-13	2.20x10 <sup>4</sup>	3.52x10 <sup>4</sup>	1.83x10 <sup>11</sup>

In Lake Teganuma total mass of sediment contaminated with radiocesium was found that decrease in 2013 and also the same with total amount of radiocesium(Table 4.2)

**Table 4.2 Total mass of sediment and total amount of radiocesium comparison in Lake Teganuma**

<b>Lake Teganuma</b>			
Time	Volume (m <sup>3</sup> )	Total Mass (Ton)	Cs <sup>134</sup> +Cs <sup>137</sup> (Bq)
Oct-12	2.78x10 <sup>5</sup>	4.44x10 <sup>5</sup>	7.41x10 <sup>11</sup>
Mar-13	2.20x10 <sup>5</sup>	3.52x10 <sup>5</sup>	6.13x10 <sup>11</sup>

**Table 4.3 Total mass of radiocesium and fluxes comparison in Ohori River and Lake Teganuma(2012-2013)**

Place	Time	Volume (m <sup>3</sup> )	Total Mass (Ton)	Cs <sup>134</sup> +Cs <sup>137</sup> (Bq)	Cs <sup>134</sup> +Cs <sup>137</sup> Flux (Bq/year)
<b>Ohori River</b>	12-Oct	2.08x10 <sup>4</sup>	3.34x10 <sup>4</sup>	2.19x10 <sup>11</sup>	3.80x10 <sup>9</sup>
	13-Mar	2.20x10 <sup>4</sup>	3.52x10 <sup>4</sup>	1.83x10 <sup>11</sup>	6.65x10 <sup>6</sup>
<b>Lake Teganuma</b>	12-Oct	2.78x10 <sup>5</sup>	4.44x10 <sup>5</sup>	7.41x10 <sup>11</sup>	-
	13-Mar	2.20x10 <sup>5</sup>	3.52x10 <sup>5</sup>	6.13x10 <sup>11</sup>	-

*Note:* Cs<sup>134</sup>+Cs<sup>137</sup> Flux (Bq/year) in 2011 was **9.72 x10<sup>9</sup>**

**Surface land = 1.9 x 10<sup>12</sup> Bq ( June 2012) calculated by concentration of radiocesium Cs<sup>134</sup>+Cs<sup>137</sup> (Bq/m<sup>2</sup>) times catchment area (m<sup>2</sup>).**

Surface land is Results of Deposition of Radioactive Cesium of the Fifth Airborne Monitoring Survey and Airborne Monitoring Survey Outside 80 km from the Fukushima Dai-ichi NPP (Decay correction: June 28, 2012) , Chiba Prefecture, Kashiwa City, The Ministry of Education, Culture, Sports, Science and Technology.

Based on these results will be discussions: 1.The movement of radiocesium concentration in the catchment, river and lake and 2. The calculation of total amount of radiocesium (Bq).

In table 4.3 The largest flux of radiocesium are found in 2011 as value 9.72x10<sup>9</sup> Bq/year and decreasing gradually in 2012 and 2013 as value 3.80 x10<sup>9</sup> Bq/year and 6.65x10<sup>6</sup> Bq/year, respectively. As the result, concentration of radiocesium was decreasing gradually because of half life of <sup>134</sup> Cs only 2 year. Most of radiocesium accumulated in land sediment as value 1.9 x 10<sup>12</sup> Bq in June 2012. In addition, total amount of radiocesium accumulated in sediment of Ohori river in October 2012 and March 2013 were 2.19x10<sup>11</sup> Bq and 1.83x10<sup>11</sup> Bq, respectively. In lake Teganuma total amount of radiocesium accumulated in sediment in October 2012 and March 2013 were 7.41x10<sup>11</sup> Bq and 6.13x10<sup>11</sup>Bq, respectively. To compare the concentration of radiocesium in catchment , flux and sediment accumulation in Ohori river and lake Teganuma, the movement of radiocesium concentration very small, most of radiocesium

attach with sediment in land soil of catchment and only 10% remain into river and lake and number of flux 2 order smaller then concentration of radiocesium accumulated in sediment of Ohori river , that mean the movement very small and most of radiocesium still remain in catchment area.

In addition, total amount of radiocesium within 6 months (October 2012 to March 2013) was decreasing almost the same in Ohori River and Lake Teganuma ranged 16% and 17%, respectively. In the addition, the results of total amount of radiocesium quite high in Ohori river if compare to the flux and total amount of radiocesium in lake Teganuma. In this case the process of calculation was considered.

Based on these results the calculation process was assumed on the calculation of Surface area in Ohori river by using Arc GIS 9.3. The shapefile calculated using the “calculate the geometry” option from the selected feature file. During created the shapefile assumed that the calculation of surface area in each point area were larger than usual , this case will be affected for larger number of total amount of radiocesium accumulated in sediment of Ohori river , for next future the calculation of surface area should be consider.

## **CHAPTER 5: CONCLUSION AND RECOMMENDATION**

The following conclusion in this study can be impressions from the result of field observation and laboratory experiments in 11 stations of Ohori River from July 2012 to March 2013 and 7 stations in Lake Teganuma compare in two times on October 2012 and March 2013 has given a value for estimated total mass of sediment and total amount of radiocesium in river and lake.

### **Field observation from July 2012 to March 2013 in Ohori River**

1. The large amount of radiocesium deposited in sediment of Ohori River showed that highest concentration and deposited remained in the lower part of river at the value greater than 30 cm depth of cesium polluted in sediment in station 9, 10 and 11. On the last of December, The highest concentration peaks was found in station 9 and 11. To interpret these results the input events of radionuclide concentration in both stations was considered and these peaks can be the base of data for determines the sediment date in the next step of research.
2. The total mass of sediment accumulated with radiocesium was estimated by using depth profile of sediment and surface area of location site. Compare results on October 2012 to March 2013, the total mass was increased in 5% in this time (within 6 months).
3. The total amount of radiocesium was estimated and Compare results on October 2012 to March 2013, the total amount of radiocesium was decreased gradually since half life of  $^{134}\text{Cs}$  only 2 years. However, the large amount of radiocesium number was high compare to the Flux of radiocesium and too considered in this finding long term of collecting samples and analysis needed.

### **Field observation on October 2012 and March 2013 in Lake Teganuma**

1. In Lake Teganuma, October 2012 the highest deposited of radiocesium is found at 18 cm of depth in station 1 and decreased from bottom on March 2013. Moreover, the highest of concentration was found in surface layer. In this finding rain event are considered can be effected in mixed layer and flux occurred in this location. In addition, the accumulation of radiocesium from station 2 to station 7(lower part of lake Teganuma) was found only in the maximum value 9 cm of depth.
2. The total mass of sediment accumulated with radiocesium was estimated by using depth of cesium polluted sediment and surface area of location site the same estimated calculation in Ohori River. Compare results on October 2012 to March 2013, the total mass was decreased around 23% in this time (within 6 months).

### **Different size of particles with Concentration of radiocesium from Land soil and sediment**

The results of experiment by selected samples from land soil in catchment and sediment in river. The size of particles in the sediment are strongly absorbed of radiocesium less than 45 $\mu$ m (Finer sand). However, for the land soil particles is strongly absorbed with the size range from 50-100  $\mu$ m, respectively. Based on this result the concentration of radiocesium absorbed in particles size in the land soil could be able some error occurred during experiment time and total amount of sample quite small. However, for this reason study on transfer of radionuclide into catchment and the absorption of radionuclide in different size fraction of land soil and sediments is important factor to study more in next future.

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