Radiocesium runoff forms and its temporal variation at two rivers in Iitate, Fukushima

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Radionuclides were released by the accident at the Fukushima Daiichi Nuclear Power Plant, and radiocesium, ^{137}Cs and ^{134}Cs, were deposited on the soil surface. All of the residents within 50 km of the plant were forced to move. Six years after the accident, some residents are expected to return. However, decontamination efforts that remove topsoil around houses, agricultural lands, and forests requires a lot of time. Focusing on the forests, it is impossible to remove all of the topsoil, and thus estimates of radiocesium movements are needed. Radiocesium is adsorbed on soil and organic matter. Their movements would be equivalent to soil particle movements, through soil erosion and sediment transport. In this study, field monitoring was conducted to estimate radiocesium runoff from two comparative watersheds. Especially, radiocesium runoff forms and its temporal variation were focused.

The study sites were two watersheds in Iitate Village, Fukushima, Japan (Figure 1). The southern observation watershed (Hiso River watershed, 25.6 km^2) has higher radiation levels compared to the northern Mano River watershed (10.8 km^2). Forest accounts for close to 75% of the land area in both watersheds. Sediments containing radiocesium carried by runoff from surrounding lands into the rivers were monitored. A monitoring system is composed of a rain gauge, water level sensor, water velocimeter, turbidity sensor, and automatic water sampler (Figure 2).

Focusing on sediment particle size, more than 75% of the ^{137}Cs was adsorbed on finer particles such as clay, silt, and fine sand which were occupied less than 50% of suspended sediment as shown in Figure 3. Correlations between suspended sediment concentrations (SSC) with ^{137}Cs concentrations in storm waters are shown in Figure 4, and were approximately linear. These results mean radiocesium was discharged with the suspended sediment and organic matter. Comparing the two watersheds in the Figure 4, the slope of the regression line at Hiso was greater than that at Mano, which means radiocesium content in the suspended sediment at Hiso was larger than that at Mano. This also agrees with the distribution of radiocesium content in the topsoil shown in Figure 1. Comparing the slope of the regression lines from 2013 to 2016 in Figure 4, it decreased clearly with the lapse of time. The decreasing ratio for three years was 79% at Hiso and 83% at Mano. These ratios are much greater than the decay ratio of 6.7% estimated by physical half-life of radio-cesium. This high decreasing ratio might have been resulted due to the selective erosion and transportation of fine particles and organic matter in the hillslope and waterway. Monitored total amounts are summarized in Table 1. Hiso radiocesium losses were greater than those at Mano even though sediment yield was smaller, and this was due to the greater concentrations of radiocesium at Hiso. Spatially averaged ^{137}Cs contents at Hiso and Mano were 1017 kBq/m^2 and 421 kBq/m^2. Thus, decontamination of radiocesium in topsoil by natural soil erosion processes may not be effective. Focusing the form of radiocesium in the river water, most of ^{137}Cs was discharged as particulate form in the storm events. Its form accounted for greater than 95% of the total ^{137}Cs amount at both watersheds.

Keywords: Radiocesium, Sediment, Soil erosion, Fukushima

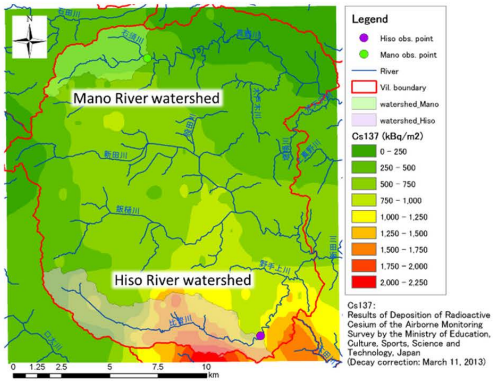

Figure 1. Study sites and ^{137}Cs levels in Iitate Village.

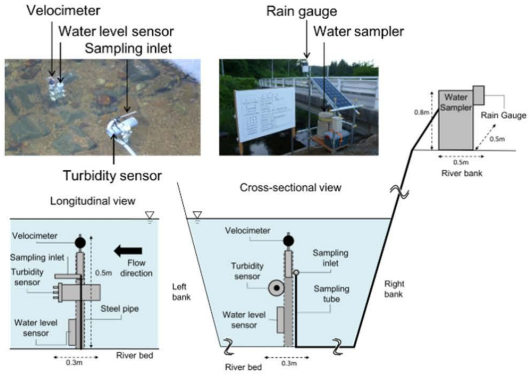

Figure 2. Instruments for field monitoring.

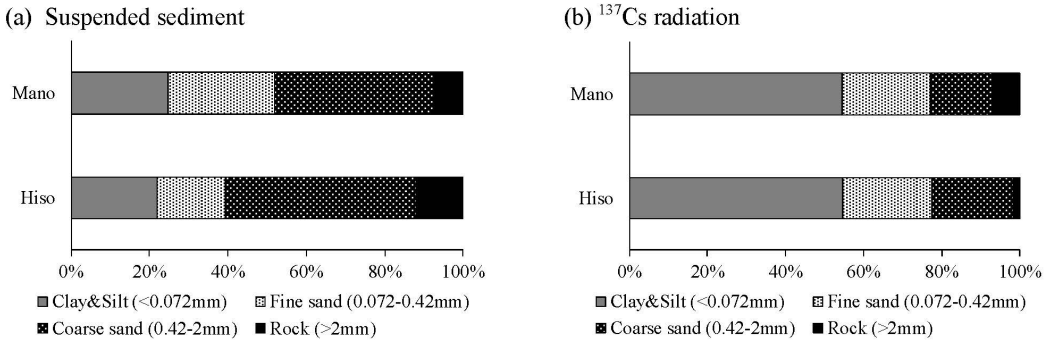

Figure 3. Ratios of each particle size in suspended sediment (a) or ^{137}Cs radiation (b) at Hiso in 2013.

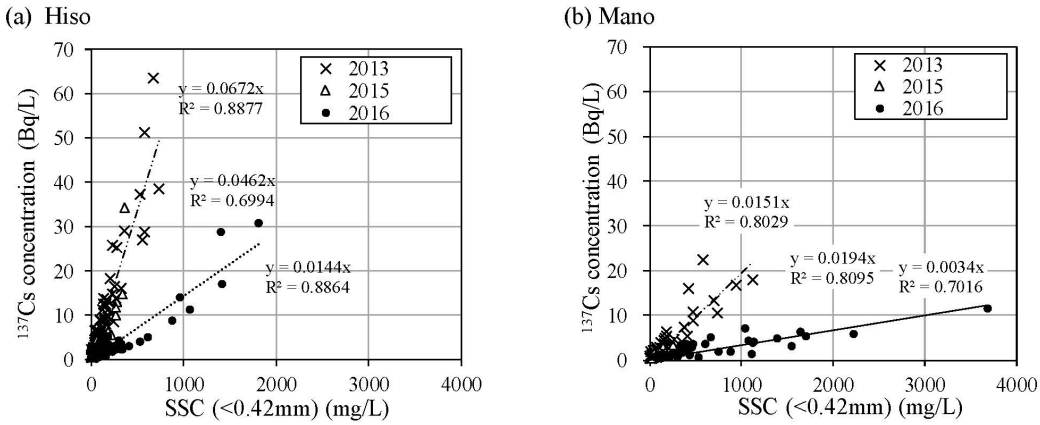

Figure 4. Relationships of SSC with ^{137}Cs concentration in the storm water at Hiso (a) and Mano (b)

Table 1. Monitored total amounts from June 2013 to December 2016.

Site	Year	Precipitation (mm)	Water runoff (mm)	Sediment yield (g/m^2)	^{137}Cs runoff (Bq/m^2)				
					Storm		Normal		Total
					Particulate	Dissolved	Particulate	Dissolved	
Mano	2013	906	574	33	647	11	10	4	705
Mano	2014	1241	997	51	693	16	18	8	776
Mano	2015	1563	573	59 *	510 *	12	8	4	525 *
Mano	2016	1319	259	25 *	69 *	2	3	2	94 *
Hiso	2013	974	562	21	1387	26	12	5	1410
Hiso	2014	1595	1234	39	1000	21	19	8	2126
Hiso	2015	1639	753	74	2502	45	13	6	2604
Hiso	2016	1394	750	55	613	20	8	3	730

*Including missing values