Development of a portable rainfall-runoff simulator for investigating pollutant transport from agricultural soil --- bromide and Cs transport ---
農地からの汚染物質の流出解析のための移動式降雨流出装置の開発 ---臭素トレーサと Cs の流出について---

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Objective:
The objective of this study is to develop a portable rainfall-runoff simulator for investigating pollutant transport from agricultural soil. The primary experiment aims to examine the runoff of bromide tracer (NaBr) and ^{134}Cs and ^{137}Cs from packed agricultural soils.

Method:

Portable Rainfall-runoff simulator development

A drip-type portable rainfall-runoff simulator was designed to be used in the laboratory and remote fieldwork. The simulator is constructed using the following principle components: a drop former setup on the simulator frame (1.5 m height), a water supply system, and micro lysimeter (15x33x48cm) which contain test soil as shown in Fig. 1. Spatial variability of the simulated rainfall was evaluated during 10 min storms replicated 6 times with Christiansen's uniformity coefficient (CU). The kinetic energy of simulated rainfall was evaluated with that of natural rainfall in Tsukuba estimated by Mihara and Wischmeier equations.,

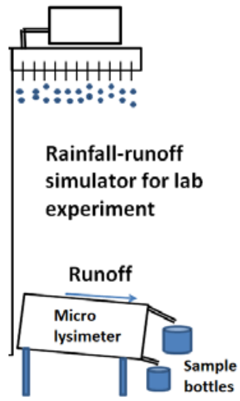

Fig. 1 Structure of rainfall simulator

Overland flow experiment

In the cesium runoff experiment, soil was taken from 15-cm surface soil from 3 locations (Lo1, Lo3, and Lo5) at Nihonmatsu city, Fukushima prefecture. Samples were sealed in plastic bags to maintain moisture content. The collected soil was sieved through 5 mm mesh and packed in lysimeter (3 cm gravel layer, 12 cm soil layer) at a wet bulk density of 1.3 g/cm^3, and 5% slope. The triplicated packed soils were exposed to 50 mm/h simulated rainfall produced by rainfall-runoff simulator (Fig. 1). Overland flow was sampled every 10 minutes after first drop of runoff. The samples were filtered by glass fiber filter (1.2 µm) to separate water and sediments. ^{134}Cs and ^{137}Cs concentrations in sediment samples were analyzed by germanium semiconductor detector.

In tracer runoff experiment, andisol soil was taken from surface soil in the university farm of Tokyo Univ. of Agriculture and Technology. The soil was then sieved through 5 mm mesh and packed for 13 cm thickness at a bulk density of 0.58 g/cm^3 and 46.5% degree of saturation on 2 cm glass bead layer in the lysimeter. NaBr was applied to the bare soil surface at the concentration of 80 ppm. Rainfall-runoff simulation was conducted for 60 minutes at 50 mm/h rain intensity after spraying NaBr tracer 1 day.

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Results and Discussion:

Performance of the portable rainfall-runoff simulator

The portable rainfall-runoff simulator is capable of producing storm intensity range from 25 to 200 mm h^{-1} intensity. At 50 mm h^{-1} intensity, average CU was approximately 80 percent. Clarke et al. (2007) achieves 87.6 percent with rainfall captured area 5 time higher than this experiment. The average drop size was estimated to be about 3.0 mm (N = 15, SD = 0.037). By using the average drop size and impact velocity from Boxel (1997),,the simulated rainfall from 1.4 m fall height was calculated to have a kinetic energy of 0.153 J m^{-2} s^{-1} which is approximately a half of the kinetic energy of natural rain on the ground in Tsukuba. Table1 shows the initial conditions and obtained runoff coefficients of this study and other previous researches. All studies were conducted on the same soil type (Clay loam). The overland flow response was found to be comparable with previous studies.

Table1. Runoff coefficient comparison among overland flow experiments

Study	Intensity (mm/h)	Slope (%)	Degree of saturation (%)	bulk density (g/cm^3)	Total precipitation (mm)	Area (m^2)	Rc
Y.Takahashi (2000)	25	8.8	-	-	43	0.70	0.02
PRRS	50	5.0	46.5	0.58	50	0.16	0.19
Onishi,T (2008)	45	14.0	75	0.62	45	0.42	0.32
Watanabe (2007)	64	6.0	-	-	64	27.30	0.47

Bromide tracer and ^{134}Cs and ^{137}Cs runoff

The initial concentrations of ^{134}Cs and ^{137}Cs in soil and those in the sediment are shown in Fig. 2. The Cs concentrations in runoff sediment samples after 30 and 60 minutes of rainfall were higher than these initial concentrations in soil. The concentrations of ^{134}Cs and ^{137}Cs in sediment collected in the first 30 min of rainfall at Lo1, Lo3 and Lo5 were 4503, 5324, and 6847 Bq/kg, respectively whereas those concentrations in the sediment collected in the last 30 min were 3597, 4911 and 4617 Bq/kg, respectively.. Yamaguchi (2012) reported that ^{134}Cs and ^{137}Cs concentrations varied depending on soil properties and organic matter.

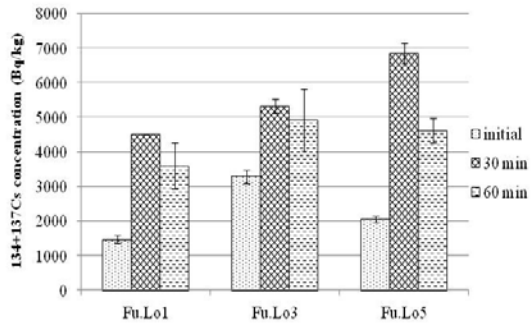

Fig. 2 $^{134+137}$Cs concentrations before/after 30 minutes of cumulative samples at three sites

For tracer experiment, NaBr concentration in runoff sample was undetectable, and most of the applied tracer was found in soil below the 5 cm layer. NaBr distribution in first top 5cm and next 5cm were 13% and 52% of applied mass, Most of the tracer was likely to infiltrate into the packed soil.

Conclusion:

A portable rainfall-runoff simulator was developed for investigating pollutant transport from agricultural soil. The rainfall-runoff simulator is able to produce homogeneous rainfall and the simulated runoff is comparable to other studies. Pollutant transport from agricultural soil such as bromide and Cs was simulated.