Journal of Environmental Radioactivity 177 (2017) 58–64

Contents lists available at ScienceDirect

Journal of Environmental Radioactivity

journal homepage: www.elsevier.com/locate/jenvrad

Radiocesium decontamination of a riverside in Fukushima, Japan

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ARTICLE INFO

Article history:
Received 15 February 2017
Received in revised form
25 May 2017
Accepted 4 June 2017

Keywords:
Radiocesium
River
Decontamination
Sediment
Air dose rate

ABSTRACT

Extensive decontamination measures have been implemented in the area affected by the Fukushima Dai-ichi nuclear disaster. Typical decontamination measures, such as removing topsoil of several centimeters in depth, are not suitable for rivers where contaminated sediments have been deposited. A decontamination measure was tested that considered the spatial distribution of radiocesium at the lower part of a tributary of the Abukuma River in Fukushima. The radiocesium distribution in the flood channel was vertically and horizontally highly heterogeneous. In some parts, the activity concentration was high (>10 kBq/kg for ^{137}Cs) even at depths of 25 cm in the sediment. This may be due to plant growth in the flood channel favoring the deposition of sediment with high activity concentration. On the basis of the radiocesium distribution, the flood channel sediment was removed to a depth of 15–35 cm, which accumulated the most radiocesium (>3.0 kBq/kg for the sum of ^{134}Cs and ^{137}Cs). The upper 5 cm of soil was removed from the dike slopes. The river bed was not decontaminated because the activity concentration was low (<1 kBq/kg) in the river bed sediment and because the water shields gamma rays emitted from the sediment. The test decontamination measure reduced the air dose rate by a factor of approximately two, demonstrating the effectiveness of our measures. Annual external doses were calculated for when this part of the dike and the flood channel is used for commuting to school and outdoor education. The doses during the activities at the test site accounted for only 1–2% of the value during daily life in the surrounding area, indicating that radiation exposure during riverside activities is limited.

1. Introduction

During the Fukushima Dai-ichi Nuclear Power Plant disaster in March 2011, several tens of petabecquerels (1 PBq = 10^{15} Bq) of radiocesium (^{134}Cs and ^{137}Cs) were released into the atmosphere (Buesseler et al., 2016) and contaminated a wide area of eastern Japan (Morino et al., 2011). The physical half-life of ^{134}Cs is relatively short (2.06 years), whereas that of ^{137}Cs is longer (30.2 years), which may cause prolonged contamination similar to the Chernobyl nuclear accident (International Atomic Energy Agency, 2006).

An extensive decontamination program has therefore been implemented over a wide area of eastern Japan to reduce radiation exposure (Ministry of the Environment, Government of Japan (MOE), 2017). The decontamination measures focus on living areas such as houses, schools, roads, parks, agricultural land, and forest adjacent to inhabited areas (MOE, 2013). Because radiocesium is characterized by strong adsorption to clay minerals (Nakao et al., 2012), most radiocesium in soil is retained in the top layer to a depth of a few centimeters (Matsuda et al., 2015). The MOE accordingly recommends soil decontamination measures, including topsoil removal, deep plowing, and covering of soil surfaces (MOE, 2013).

According to the MOE decontamination guidelines (MOE, 2013), living areas also include frequently used riverside parks and playing fields. Sediments containing radiocesium may be deposited on riversides during floods; thus, the radiocesium inventory is sometimes greater on these sediments than in the surrounding area (Burrough et al., 1999; Konoplev et al., 2016). However, sediment deposition is highly heterogeneous and sediment erosion occurs continuously. Consequently, the radiocesium distribution on river banks and reservoirs is expected to be vertically and horizontally heterogeneous. For such conditions, standard soil decontamination measures, where only the top layer is removed, are not suitable for riversides, and appropriate decontamination measures have not been established. In this study, we tested a decontamination measure based on the vertical and horizontal distribution of radiocesium at a river in Fukushima.

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http://dx.doi.org/10.1016/j.jenvrad.2017.06.005
0265-931X/

2. Materials and methods

2.1. Site description

The test site was 55 km northwest of the Fukushima Dai-ichi Nuclear Power Plant (N37°46′2″, 140°34′49″) and at the lower part of the Kami-Oguni River (Fig. 1a and b), a tributary of the Abukuma River, which is the largest river in Fukushima. The total deposition density of ^{134}Cs and ^{137}Cs was 440 kBq/m^2 (decay correction date: July 2, 2011), and the air dose rate at 1 m above the ground was 0.9 μSv/h on November 7, 2014, according to the airborne monitoring survey (Nuclear Regulation Authority, 2017). The annual mean temperature and precipitation in the period 2006 to 2015 were 12.7°C and 1160 mm, respectively, observed at the AMeDAS Yanagawa station 9 km north of the test site (Japan Meteorological Agency (JMA), 2017). The area and the elevation of the Kami-Oguni River watershed are 13.2 km^2 and 110–580 m, respectively (Fig. 1b), calculated from data provided by the Ministry of Land, Infrastructure, Transport and Tourism (MLIT, 2017). The lower parts of the catchment are used as residential areas and for agriculture, and the hilly area is covered with forest (Fig. 1c). The residential land, agricultural land, and forest account for 2%, 22%,

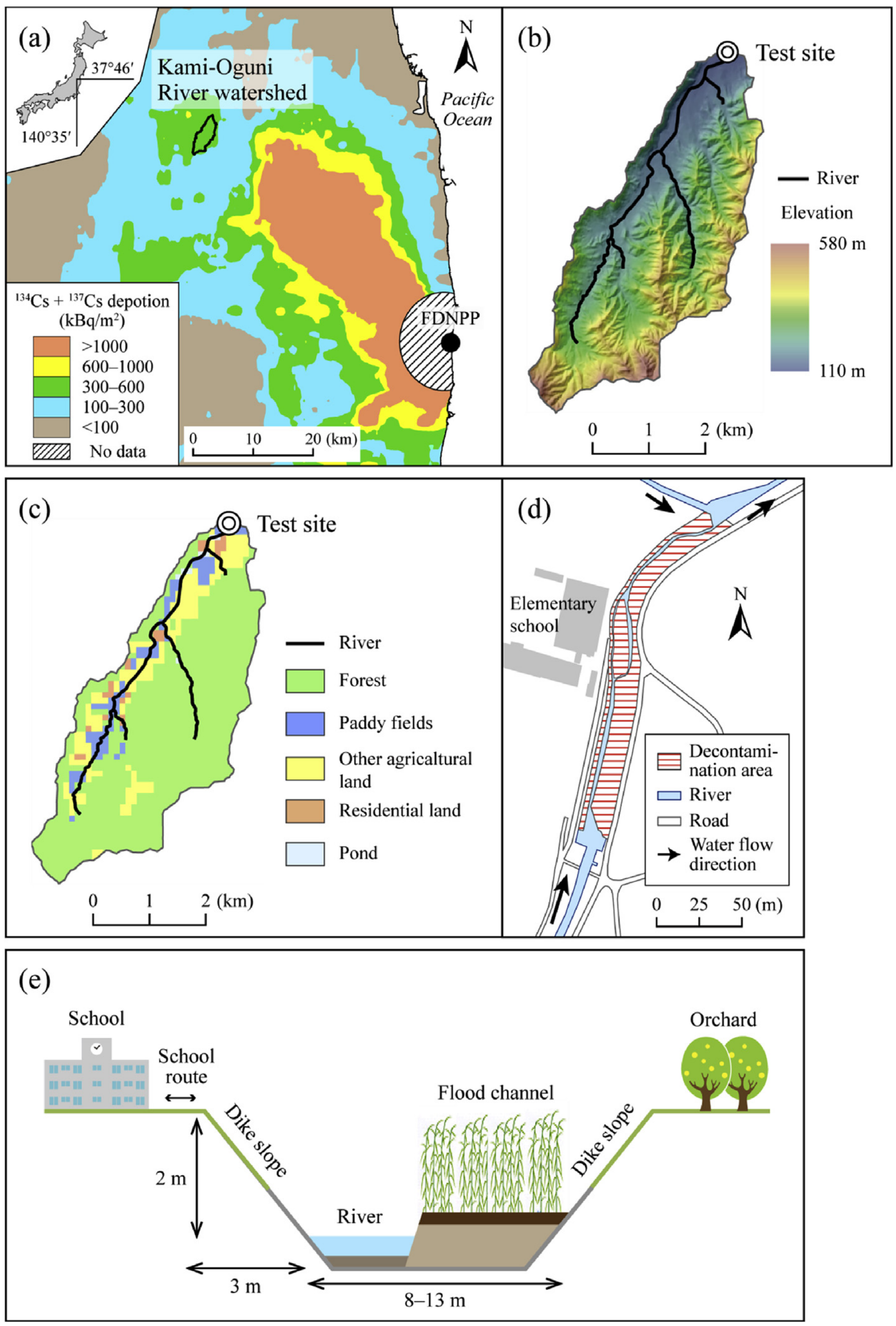

Fig. 1. Map of the Kami-Oguni River watershed (a), topographic map of the watershed (b), land-use map of the watershed (c), the decontamination area in the test site (d), and schematic cross-section of the test site (e). Radiocesium deposition densities (decay correction date: July 2, 2011) are derived from the third airborne monitoring survey data (Ministry of Education, Culture, Sports, Science and Technology, 2011). Various landscape elements are cited from data provided by MLIT (2017).