Available online at www.sciencedirect.com

ScienceDirect

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

Distribution of dissolved and particulate radiocesium concentrations along rivers and the relations between radiocesium concentration and deposition after the nuclear power plant accident in Fukushima

Hideki Tsuji [a], *Tetsuo Yasutaka* [a,*], *Yoshishige Kawabe* [a], *Takeo Onishi* [b], *Takeshi Komai* [c]

[a] *National Institute of Advanced Industrial Science and Technology, 1-1-1 Higashi, Tsukuba, Ibaraki 305-8567, Japan*
[b] *Faculty of Applied Biological Sciences, Gifu University, 1-1 Yanagito, Gifu 501-1193, Japan*
[c] *Graduate School of Environmental Studies, Tohoku University, 6-6-20 Aramaki-Aza-Aoba, Aoba-ku, Sendai, Miyagi 980-8579, Japan*

ARTICLE INFO

Article history:
Received 15 November 2013
Received in revised form
3 April 2014
Accepted 13 April 2014
Available online 24 April 2014

Keywords:
Dissolved radiocesium
Particulate radiocesium
Deposition
River water
Fukushima
Regression analysis

ABSTRACT

This study involved measurement of concentrations of dissolved and particulate radiocesium (^{134}Cs and ^{137}Cs) in river water, and determination of the quantitative relations between the amount of deposited ^{137}Cs and ^{137}Cs concentrations in river waters after the Fukushima Daiichi nuclear power plant accident. First, the current concentrations of dissolved and particulate ^{134}Cs$\cdot{}^{137}$Cs were determined in a river watershed from 20 sampling locations in four contaminated rivers (Abukuma, Kuchibuto, Shakado, and Ota).

Distribution characteristics of different ^{137}Cs forms varied with rivers. Moreover, a higher dissolved ^{137}Cs concentration was observed at the sampling location where the ^{137}Cs deposition occurred much more heavily. In contrast, particulate ^{137}Cs concentration along the river was quite irregular, because fluctuations in suspended solids concentrations occur easily from disturbance and heavy precipitation. A similar tendency with dissolved ^{137}Cs distribution was observed for the ^{137}Cs concentration per unit weight of suspended solids.

Regression analysis between deposited ^{137}Cs and dissolved/particulate ^{137}Cs concentrations was performed for the four rivers. The results showed a strong correlation between deposited ^{137}Cs and dissolved ^{137}Cs, and a relatively weak correlation between deposited ^{137}Cs and particulate ^{137}Cs concentration for each river. However, if the particulate ^{137}Cs concentration was converted to ^{137}Cs concentration per unit weight of suspended solid, the values showed a strong correlation with deposited ^{137}Cs.

* *Corresponding author*. Tel.: +81 29 849 1545; fax: +81 29 861 8109.
E-mail address: t.yasutaka@aist.go.jp (T. Yasutaka).
http://dx.doi.org/10.1016/j.watres.2014.04.024
0043-1354/

1. Introduction

A significant amount of radiocesium (mainly ^{134}Cs and ^{137}Cs) was released into the atmosphere and deposited on land from the accident at the Fukushima Daiichi Nuclear Power Plant (FDNPP). In the years following the accident, the radiocesium stored mainly in forests and mountains gradually flowed into mountain streams and rivers through rainfall events (Nagao et al., 2013; Ueda et al., 2013). Since rivers can transfer chemicals a great distance, continual monitoring of river water is important for estimating downstream environmental impacts.

Cesium concentrations in river waters can be divided into two main forms: dissolved and particulate. Dissolved radiocesium exists as cesium ions and cesium ion hydrates, which migrate relatively quickly with water flow and can contaminate plants *via* root uptake (Zhu and Smolders, 2000). In current agricultural sites, some dissolved radiocesium can migrate by irrigation into paddy fields or into water supplies for hydroponics. In contrast, cesium ions from particulate radiocesium are absorbed mainly onto soil particles (Evans et al., 1983; Comans et al., 1991), which exist as suspended solids (SS) in the water and may cause secondary contamination due to sediment runoff (Walling and Bradley, 1990). The difference in these environmental behaviors requires that both forms of radiocesium must be monitored.

Several reports have described the distribution of dissolved or particulate radioactive materials in environmental waters after the Chernobyl accident using either field surveys (Kryshev, 1995; Vakulovsky et al., 1994; Matsunaga et al., 1998) or model simulations (Smith et al., 2004; McDougall et al., 1991). These studies investigated actual conditions for the temporal distribution of radiocesium, decay of radiocesium with time, and behavior of soil containing radiocesium near the Chernobyl Nuclear Power Plant. However, the climate and topography around Fukushima are different from Chernobyl. For example, annual precipitation in Fukushima is 3-fold greater than that of Chernobyl, and the radiocesium was

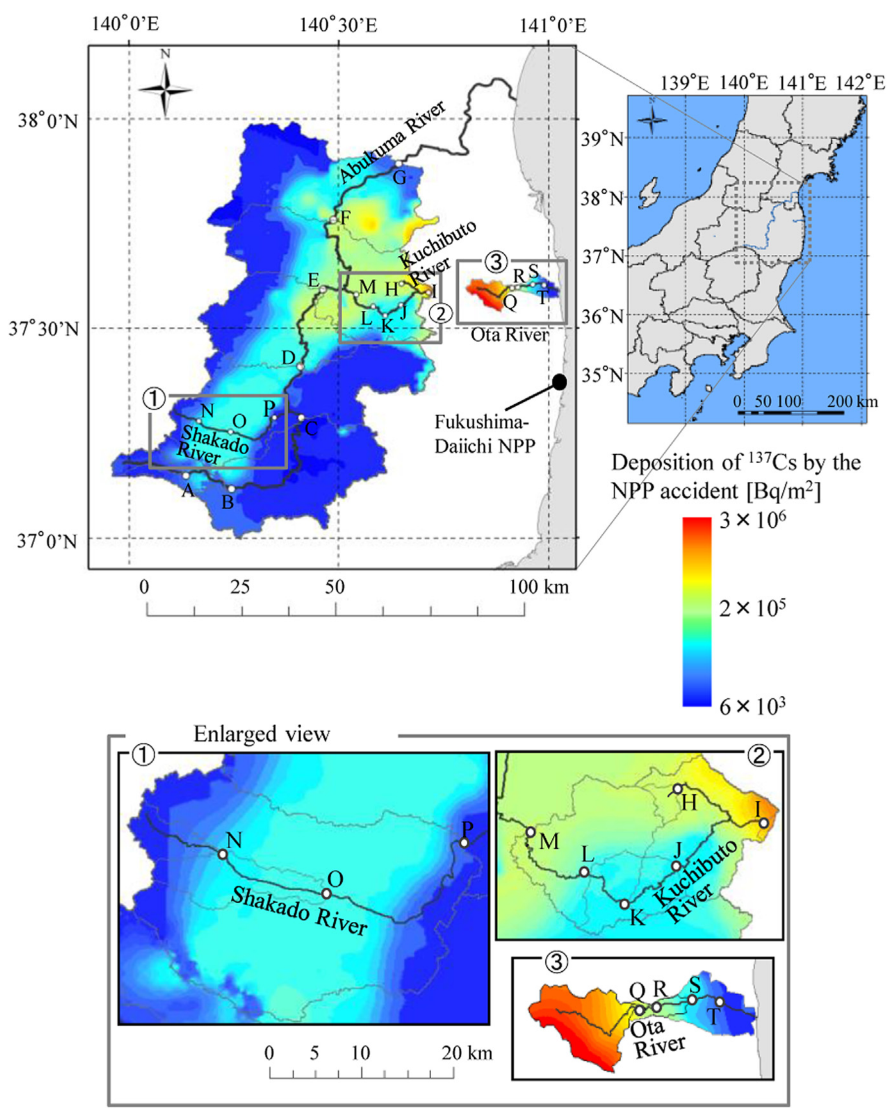

Fig. 1 – Sampling location and ^{137}Cs deposition distribution after the Fukushima NPP accident in the Abukuma River, Kuchibuto River, Shakado River, and Ota River watersheds.