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Impact on ambient dose rate in metropolitan Tokyo from the Fukushima Daiichi Nuclear Power Plant accident

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ABSTRACT

A car-borne survey was made in metropolitan Tokyo, Japan, in December 2014 to estimate external dose. This survey was conducted for all municipalities of Tokyo and the results were compared with measurements done in 2003. The ambient dose rate measured in the whole area of Tokyo in December 2014 was 60 nGy h^{-1} (23–142 nGy h^{-1}), which was 24% higher than the rate in 2003. Higher dose rates (>70 nGy h^{-1}) were observed on the eastern and western ends of Tokyo; furthermore, the contribution ratio from artificial radionuclides (^{134}Cs and ^{137}Cs) to ambient dose rate in eastern Tokyo was twice as high as that of western Tokyo. Based on the measured ambient dose rate, the effective dose rate after the accident was estimated to be 0.45 μSv h^{-1} in Tokyo. This value was 22% higher than the value before the accident as of December 2014.

1. Introduction

Large amounts of artificial radionuclides were released from the reactors into the environment in the March 2011 accident at the Fukushima Daiichi Nuclear Power Plant (F1-NPP) of the Tokyo Electric Power Company (TEPCO). The released amounts of artificial radionuclides, excluding those directly dispersed in the direction of the ocean, were estimated to be: 0.6–1.9 × 10^{19} Bq of ^{133}Xe, 0.7–5.0 × 10^{17} Bq of ^{131}I and 1.0–5.0 × 10^{16} Bq of ^{137}Cs (Koo et al., 2014). For ^{137}Cs, this value is about 42% of the estimated amount emitted in the 1986 Chernobyl accident (Stohl et al., 2012). According to the simulation study by Koo et al. (2014), for the ^{137}Cs released into the atmosphere, 20% was deposited onto the land of Japan and the other 80% was transported to the ocean or other areas of the northern hemisphere. For the Japanese land deposition, most of the artificial radionuclides deposited on the ground in a northeastern area from the F1-NPP (Yoshikawa et al., 2014), but some of the artificial radionuclides were subsequently diffused within an altitude of 0–1000 m from ground level and deposited on southern and southwestern areas depending on the topography, wind direction and precipitation field (Kinoshita et al., 2011; Morino et al., 2011). Especially, the distribution of artificial radionuclides was affected by the land altitudes because the southern and southwestern areas from the F1-NPP are mixes of mountainous regions (altitudes of 600–800 m) and flatlands.

In metropolitan Tokyo (Fig. 1A), the artificial radionuclides were wet-deposited on March 21–23 by rainfalls (Kinoshita et al., 2011; Morino et al., 2011). In fact, artificial radionuclides such as ^{131}I, ^{132}I, ^{132}Te, ^{134}Cs, ^{136}Cs, and ^{137}Cs were observed on March 22 at the Canadian embassy located in Tokyo (Zhang et al., 2013). According to the results of air-borne monitoring done in September 2011 for Tokyo by the Ministry of Education, Culture, Sports, Science and Technology, Japan (Ministry of Education, Culture, Sports, Science and Technology, 2011), higher ambient dose rates were observed on the eastern and western ends of Tokyo. Air-borne radiation monitoring has been continuously performed, mainly by the Japan Atomic Energy Agency (JAEA) (Yuuki et al., 2014). The high dose rate areas (i.e. within 80 km from F1-NPP) continue to be conscientiously monitored; however, metropolitan Tokyo has not been included in those monitoring areas since May 2012. Andoh et al. (2015) have also made car-borne surveys in eastern Japan since

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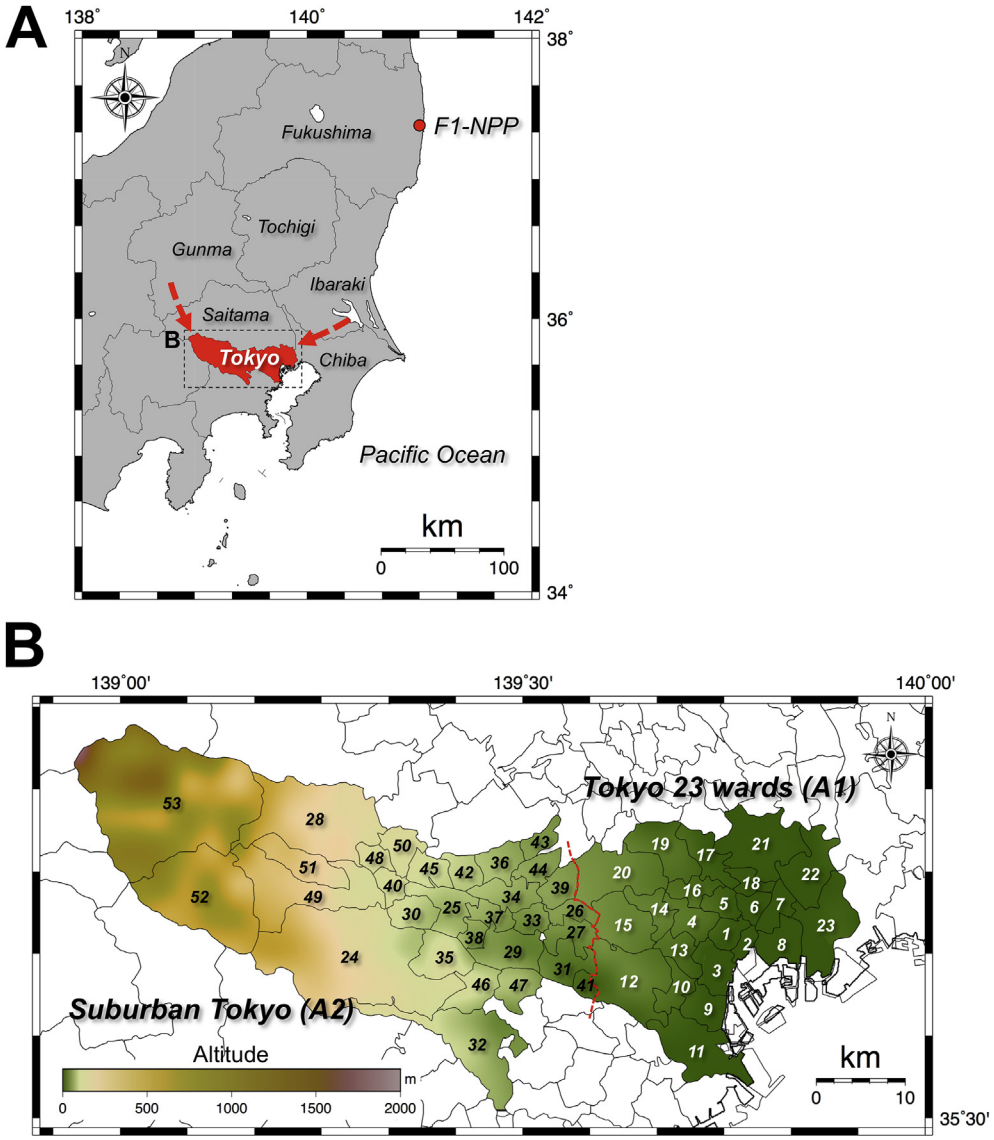

Fig. 1. A Map showing locations of Tokyo and the Fukushima Daiichi Nuclear Power Plant (F1-NPP). Red arrows explain deposition pathways of artificial radionuclides from F1-NPP (Torii et al., 2012; Yuuki et al., 2014). B Map showing Tokyo municipalities consisting of 23 wards and 30 cities, towns and villages. The number for each administrative district (#1 - #53) is an ID number that is given in this paper by reference to the Japanese Industrial Standards. The color scale gives the altitudes within the districts. These maps were drawn using the Generic Mapping Tools of Wessel and Smith (1991). (For interpretation of the references to color in this figure legend, the reader is referred to the web version of this article.)

June 2011. However, the whole metropolitan Tokyo area has not been included in these surveys. The Tokyo Metropolitan Government also carried out measurement of the ambient dose rates at 1 m from the ground surface using NaI(Tl) scintillation survey meters at 100 locations in Tokyo in June 2011 (Tokyo Metropolitan Government, 2011). Currently, ambient dose rates at eight locations in Tokyo are provided on a website by the Tokyo Metropolitan Institute of Public Health (Tokyo Metropolitan Institute of Public Health (2015)). However, these "point" data are not sufficient to obtain a complete view of the ambient dose rate in Tokyo and to evaluate safeguarding of the health of area residents.

Measurements for the whole metropolitan Tokyo area should be continually performed to estimate the migration of radionuclides because ambient dose rate has been drastically changed by rainfall, natural decay of radionuclides and decontamination work. Especially, there have been no reports about the migration of artificial radionuclides in big cities which have large areas covered with asphalt and concrete. In addition, it is necessary to consider the presence of natural radionuclides such as ^{40}K, ^{238}U series and ^{232}Th series (i.e., background) to more accurately assess the impact from the accident. The authors recently reported detailed data for ambient dose rates (n = 669) measured in 2003 for Tokyo (excluding the Pacific Ocean islands that are within the Tokyo Government's jurisdiction) (Inoue et al., 2015a). The arithmetic average ambient dose rates were 47 nGy h^{-1} (18–61 nGy h^{-1}) in the eastern area of Tokyo (A1 in Fig. 1B) and 54 nGy h^{-1} (34–76 nGy h^{-1}) in the western area (A2 in Fig. 1B), and there was some dependence of the dose rates on the geological age and the natural environments.

No severe nuclear power plant accident has occurred that engulfed a large metropolitan center such as Tokyo where 13.35 million people live (the F1-NPP is more than 200 km from Tokyo). Easy-to-understand and accurate information about ambient dose rate in Tokyo is desired by local governmental agencies,