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Overview

Radioactive Doses — Predicted and Actual — and Likely Health Effects

S. Nagataki *, N. Takamura †

* Nagasaki University, Nagasaki, Japan
† Department of Global Health, Medicine and Welfare, Atomic Bomb Disease Institute, Nagasaki University, Nagasaki, Japan

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Abstract

Five years have passed since the nuclear accident at Fukushima Daiichi Nuclear Power Stations on 11 March 2011. Here we refer to reports from international organisations as sources of predicted values obtained from environmental monitoring and dose estimation models, and reports from various institutes in Japan are used as sources of individual actual values. The World Health Organization, based on information available up to 11 September 2011 (and published in 2012), reported that characteristic effective doses in the first year after the accident, to all age groups, were estimated to be in the 10–50 mSv dose band in example locations in evacuation areas. Estimated characteristic thyroid doses to infants in Namie Town were within the 100–200 mSv dose band. A report from the United Nations Scientific Committee on the Effects of Atomic Radiation published in 2014 shows that the effective dose received by adults in evacuation areas during the first year after the accident was 1.1–13 mSv. The absorbed dose to the thyroid in evacuated settlements was 7.2–35 mSv in adults and 15–83 mSv in 1-year-old infants. Individual external radiation exposure in the initial 4 months after the accident, estimated by superimposing individual behaviour data on to a daily dose rate map, was less than 3 mSv in 93.9% of residents (maximum 15 mSv) in evacuation areas. Actual individual thyroid equivalent doses were less than 15 mSv in 98.8% of children (maximum 25 mSv) in evacuation areas. When uncertainty exists in dose estimation models, it may be sensible to err on the side of caution, and final estimated doses are often much greater than actual radiation doses. However, overestimation of the dose at the time of an accident has a great influence on the psychology of residents. More than 100 000 residents have not returned to the evacuation areas 5 years after the Fukushima accident because of the social and mental effects during the initial period of the disaster. Estimates of radiation doses placed in the public domain must be based on scientific evidence, and the way such information is communicated to residents should be carefully considered to avoid psychosocial effects that may have a greater bearing on health than the radiation itself.

Key words: Effective radiation dose; Fukushima; nuclear reactor accident; radiation; thyroid

Statement of Search Strategies Used and Sources of Information

This paper reflects expert opinion and current literature accessed by the authors; no formal search strategy has been defined.

Introduction

A nuclear accident at the Tokyo Electric Power Company Fukushima Daiichi Nuclear Power Stations (FDNPS) occurred on 11 March 2011. In the 5 years since the accident, numerous papers on radioactive doses in the area, both predicted and actual, have been published by international organisations, such as the World Health Organization (WHO) [1], the United Nations Scientific Committee on the Effects of Atomic Radiation (UNSCEAR) [2], the International Atomic Energy Agency (IAEA) [3] and many research institutes in Japan [4–12]. In this overview, the reports from WHO and UNSCEAR are used as sources of predicted radioactive dose values from environmental monitoring and dose estimate models, and many papers from research institutes in Japan are referred to as sources of individual estimated or measured values.

When uncertainty exists in dose estimation models, safety and protection concerns often result in the final estimated doses being much greater than the actual radiation doses. Estimation of radiation doses must be made on a scientific basis and the results must be announced to the

Author for correspondence: S. Nagataki, Radiation Effects Association, 1-9-16 Kajicho, Chiyodaku, Tokyo 101-0044, Japan. Tel: +81-3-5295-1481.
E-mail address: shigenobu.nagataki@nifty.com (S. Nagataki).

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public as soon as possible. However, the public announcement of predicted radiation doses in the initial period after an accident has a strong influence on the psychology of residents and how such information is communicated should be considered not only from the standpoint of radiation safety and protection, but also from the standpoint of accurate risk communication.

Outline of the Fukushima Nuclear Reactor Accident

The Great East Japan Earthquake, the largest in the history of Japan, occurred on 11 March 2011. The earthquake and resulting tsunami triggered a nuclear reactor accident at the FDNPS [13,14]. At 14:46, the earthquake triggered automatic shutdown of the FDNPS. All six external power supply sources malfunctioned after the earthquake and emergency diesel power generators were started. However, at 15:37, the tsunami struck the emergency diesel generators and distribution boards, causing loss of all power supplies. The water level dropped in the reactors and the nuclear fuel was exposed, leading to a core melt. These events resulted in a large amount of radionuclide released into the atmosphere. The estimated total release assumed by UNSCEAR for iodine-131 (I-131), caesium-134 (Cs-134) and caesium-137 (Cs-137) was 120, 9.0 and 8.8 PBq [2], respectively. Figure 1a shows the results of airborne monitoring by the Ministry of Education, Culture, Sports, Science and Technology and the United States Department of Energy, as expressed in μSv/h at 1 m from the ground on 29 April 2011 [15,16]. Figure 1b shows areas of evacuation, restricted areas and deliberate evacuation areas.

Actions Taken to Decrease Radiation Exposure after the Fukushima Accident

As shown in Table 1, the Governor of Fukushima Prefecture issued instructions at 20:50 on 11 March 2011 for the evacuation of settlements within 2 km of the FDNPS. At 21:23, the Prime Minister ordered the evacuation of individuals within 3 km of the FDNPS and for all individuals within 10 km to remain sheltered indoors. At 18:25 on 12 March the evacuation radius was expanded to 20 km. On 15 March 2011, instructions were issued ordering all people living between 20 and 30 km of the FDNPS to shelter indoors [2,3,13,14]. On 16 March 2011, Japanese and prefectural governments began to monitor select foodstuffs (milk, vegetables, grains, meat, fish and others). Foods containing

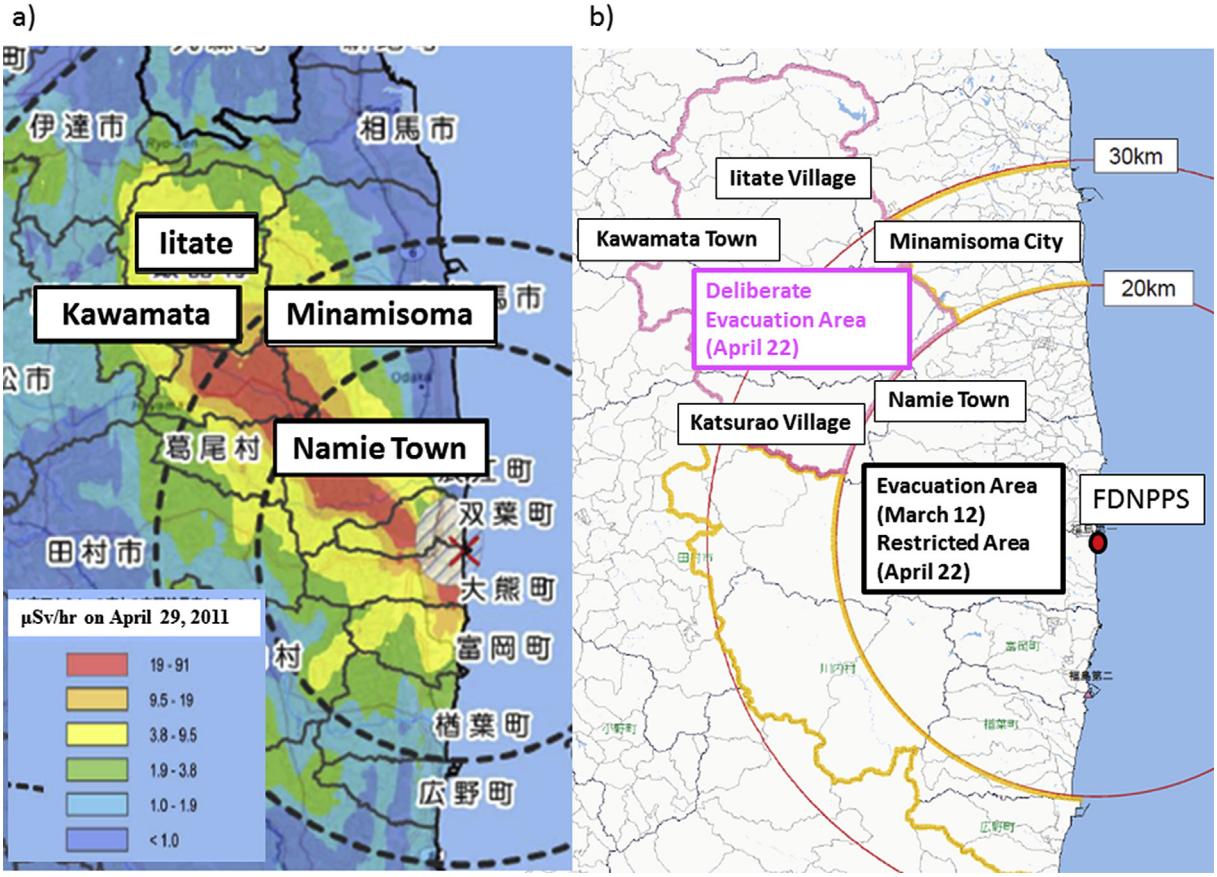

Fig 1. (a) Airborne monitoring of radioactivity 1 m from the ground on 29 April 2011; radioactivity expressed as μSv/h. (b) Evacuation areas and restricted areas (12 March 2011) and deliberate evacuation areas (22 April 2011). Entry into evacuation and restricted areas was prohibited for all except emergency response workers; temporary entry was sometimes granted (by mayors of the region's municipalities). Deliberate evacuation areas were areas in which authorities were concerned that the cumulative radiation dose might reach 20 mSv within 1 year after the accident. Residents were requested to evacuate in a planned manner (within about 1 month).