Radioactive Pollution of Fukushima Daiichi Nuclear Power Plant by Particle Model

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1. INTRODUCTION

At 14:46 on March 11, 2011, the great earthquake with magnitude of 9.0 occurred from a focus of Sanriku-oki. From Hokkaido to Kyushu, all Japan was attacked with a big shake and Tsunami. In record, it was the maximum in Japan and the greatest of the world with 20335 of victims. At 15:50, the great tsunami attacked Fukushima Daiichi Nuclear Power Plants, Tokyo Electric Power Company. The emergent core cooling system did not work and lost cooling ability. Fukushima Daiichi had meltdown at Reactor 1, and a hydrogen explosion occurred, which made building structures flying to pieces and a big amount of isotopes leaking into the atmosphere. Reactors 2 and 3 also had meltdown in the same way. Reactor 4 was fired. In Fukushima Daiichi Nuclear Power Plant, four times of hydrogen explosions occured in order of reactor 1 (Mar 12), reactor 3 (Mar 14), reactor 4 (Mar 15), and reactor 2 (Mar 16). However, radioisotope leaks contributed mostly pollution and was different from the explosions. The eastern part of Fukushima including Iitate village was polluted with radioisotope leaks on Mar 12, 15-16, 18 and 20.
Here, the pollutions were estimated four times of radioactive leaks by a particle model.

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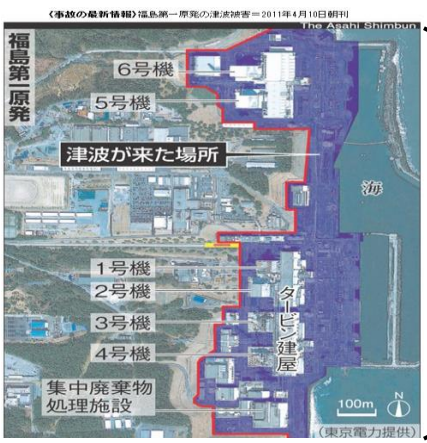

Fig. 1 Overview of Tsunami disaster (Tokyo Electric Power Company)

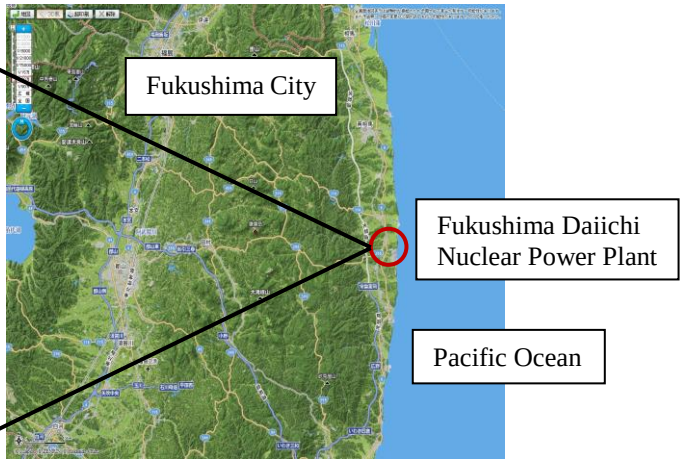

Fig.2 Map of Fukushima

2. METHODS

The study area was East Fukushima where was most contaminated from March 11 to 31, 2011.
Here, a particle model was used in substitution for the atmospheric diffusion model that had been used conventionally. In the particle model, different particle sizes and different heights were selected. Each particle has falling speed by the following Stokes equation.

$$v_s = \frac{D^2(\rho_p - \rho_a)}{18\mu}$$

where v_s: falling velocity (m), ρ_p: particle density, 2650kg/m^3, ρ_a: air density, 1.225kg/m^3, μ : viscosity, $1.8 \cdot 10^{-5}$Pas.
The specific gravity of the particle was assumed by 2.65. The particle size has ten kinds of 0.01mm - 0.1mm. The direction of the wind, the wind velocity in 5km mesh and eight kinds of altitudes of 10m - 3,000m were selected. DEM changed from 30m mesh to 1km mesh.

3. RESULTS

Hydrogen explosions each reactor at Fukushima Nuclear Power Plant. It started on March 12. Next was on March 15. Flying trace of particles each different particle size on March 12, 15, 18 and 20. Particle sizes are 0.01, 0.02, 0.03, 0.04, 0.05, 0.06, 0.07, 0.09 and 0.1mm. The flying traces are shown in three dimensions. Each particle dropped with rain cloud on March 15.
Almost places surpass 100m above the sea level in 10km from Fukushima Nuclear Power Plant to the Fukushima direction. The diffusion of the particle did not cause by wind less than 100m in height. In the pollution of Fukushima nuclear plant accident, wind and the topography greatly influenced it. Because most particles hit the mountain slopes, wind of 100m in height was not more likely to influence pollution in Fukushima city. In addition, the wind at 300m on March 12 and more than 1,250m on March 15 didn't influence pollution of the land because of flying to the Pacific Ocean. The fall spot of a different particle estimated from the direction of the wind, the wind velocity on March 15. The big particle dropped within the range of approximately 20km. The fall spots were spread by the rainfall cloud. Figure.3 shows radioisotope pollution

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on Mar 12 to 20. In addition, the Iitate village was polluted.

4. DISCUSSION

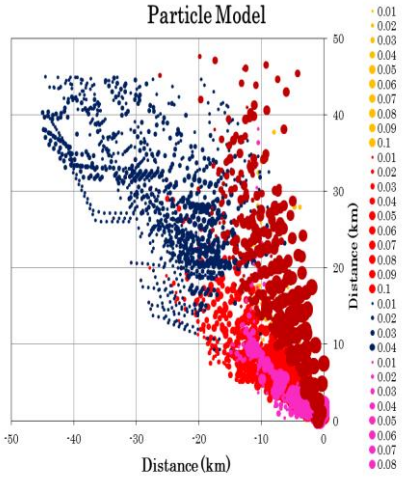

Fig. 3 Radioisotope pollution on Mar 12 to 20

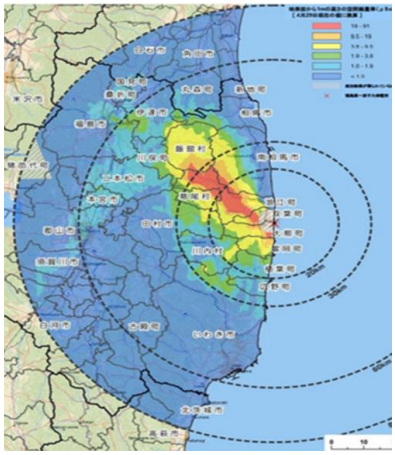

Fig.4 Spatial radio isotope dose

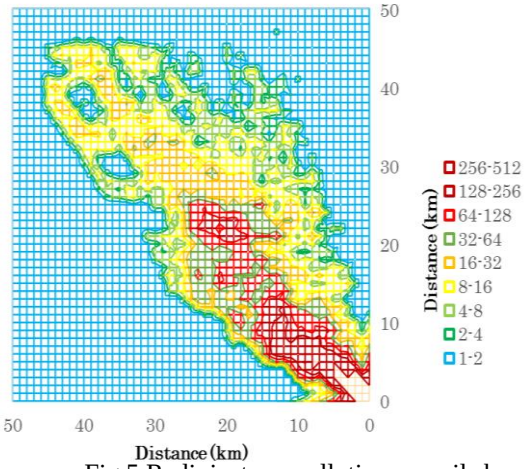

Fig.5 Radioisotope pollution on soils by the particle model (unit: μSv/hr)

4.1 Particle Model and Atmospheric Diffusion Model

Radioisotope pollution was analyzed by the atmospheric diffusion model traditionally. This model was assumed the pollution to be a normal distribution with the standard deviation determined by the weather conditions. In contrast, the particle model in this research to make many particles with different diameters fly in different heights and fall with Stokes equation. Both the standard deviations and deposit speeds are unified to simple particle falling movement. But, in wet deposit, flying particles fall through the wind paths. In the particle model, falling particles are changed to the concentration (spatial dose). Here, the number of particles is changed to the spatial dose on the earth. The number of particles was 7600. One particle/m^2 equals to 2μSv/hr. Comparing the distribution maps shown in Figs. 4 and 5, 0.04mm diameter particles seemed to fall down most.

4.2 Spatial Resolution and Temporal Resolution

The weather data used for the particle model were the weather archive by the meso-model and observation data of the Meteorological Agency. The altitudes in 1km mesh were obtained from 30m mesh DEM in Geospatial Information Authority. The meteorological archive gave wind velocity and directions in 5km mesh hourly in 8 classes of altitudes. The wind speeds were categorized into 5 grades and the wind directions were continuous values. These discrete values determined calculation accuracy. To improve the accuracy, the resolutions should be finer than this research.

5. CONCLUSIONS

(1) The radioisotope pollution for Iidate village from Fukushima Daiichi Power Plant was emitted by the leak mainly on March 15.
(2) The radioisotope pollution from Fukushima Daiichi Nuclear Power Plant was not approach Fukushima city because of high mountains.
(3) The radioisotope pollution in Fukushima occurred in dry and wet deposits.
(4) The dry deposit might make the pollution pattern similar to the watershed, while the wet deposit might make the pollution pattern similar to cloud images or rainfall distribution.

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