B-22 Secondary pollution of Fukushima nuclear power plant

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1. INTRODUCTION

On March 11, 2011, Fukushima Daiichi nuclear power plant was attacked by the great earthquake and stopped by tsunami. Emergency core cooling systems did not work, three reactors in Dai-ichi nuclear power plant became meltdown and hydrogen exploded to break the buildings. Finally a big amount of radioisotopes were emitted to the sky and polluted eastern Japan. Especially the northwest area of the plant was polluted severely and the residents escaped. The pollution covers the atmosphere, hydrosphere and the geosphere, and the secondary pollution is progressing. Here, the northwest area pollution was analyzed in the atmosphere and hydrosphere pollution, especially groundwater and ocean pollutions. The atmospheric pollution was analyzed for transportation by the wind from pollution areas over Abukuma plateau. Hydrosphere pollution was estimated in the watershed for rivers and groundwater pollution by runoff.

2. METHOD

(1) Data used

Satellite data were ALOS, THEOS and ASTER. From the database on the research of radioactive substances distribution by Nuclear Regulation Authority, two spatial dose maps were selected on April 19, 2011 and June 28, 2012. From the homepage of Fukushima prefecture, land use data were obtained and calculated to runoff ratios by Table 1, which shows runoff ratios each land use. These values indicate near runoff ratios of radioisotopes by rainfall. Rainfall data were obtained from Meteorological Agency as shown in Table 2. Evapotranspiration data were obtained from Watanabe (1987). Major radioisotopes are 6 nuclides as shown in Table 3.

Table 1 Runoff ratio each land use.

Agricultural field	Grass field	Forest	Residence	Public area
0.45	0.45	0.1	0.6	0.4

Table 2 Annual rainfall (mm)

Year	Kawauchi	Hirono	Namie	Souma	Onahama
2011	1270	1365.5	1320.5	1316	1013.8
2012	1481.5	1636.5	1471	1405.5	1013.4

Table 3 Major radioisotope nuclides (2011)

Nuclide	Te132	I131	I132	I133	Cs134	Cs137
Half life	0.00877	0.0219	0.000263	0.0024	2.1	30
Ratio	0.135	0.568	0.153	0.0418	0.0398	0.0618

(2) Water budget

Water budget was calculated annually as next.

$$\text{Rainfall} = \text{Evapotranspiration} + \text{Runoff} + \text{Infiltration} \quad (1)$$

where each item unit is mm annually.

(3) Material budget

Cs 137 dose was calculated by the next equation.

$$1\mu\text{Sv/h of Cs 137} = 0.308\ \text{MBq/m}^2 \quad (2)$$

Each radioisotope dose was estimated by half life span as shown in Table 3.

3. RESULTS

(1) Reduction of spatial dose

The reduction of spatial dose between 2011 and 2012 was 0.48. This value constitutes 0.68 reduced by half life period and 0.7 reduced by runoff, which corresponds to runoff ratio 0.3. In the objective area of 30 km circle, the east slope on the Abukuma Plateau has runoff ratio 0.26. Therefore, the residual radioisotopes still exist on the surface with ratio 0.7. The annual rainfall on the east Abukuma plateau was 1329 mm on average. Evapotranspiration was estimated as 680 mm (Watanabe, 1987). The total spatial dose in 2011 was 5997 TBq for 80 km circle as Cs 137 equivalent, while the dose in 2012 was 3310 TBq.

(2) Secondary pollution

Hydrogen explosion occurred at the 3rd reactor at 11:00 on March 14, by southeast wind the radioisotopes flowed to Mt. Reizen and fell down the east slope of Abukuma plateau. The radioisotopes on concrete debris born by a hydrogen explosion flowed at less than 1000 m height in the direction of northwest and fell down near the ridge between Mt. Reizen (825 m) and Mt. Tenno (1057 m). A part of them passed over the ridge and flowed to Kawamata City.

However, in the spatial dose distributions unknown paterns were recognised. Figures 1 and 2 show the distributions of radioisotopes moving south from Kawamata City to National route 4. From the meteorological data, such a wind trajectry was unseen and these patterns may occur by the secondary pollution. In the same way, such a pattern was recognised on the southwest of the nuclear power plant. That sugests from the isotopes over the east slope of the Abukuma Plateau in northwest direction of the nuclear power plant might diffuse to south southwest by rainfall and the transpotation by vehicles and trains as the secondary pollution.

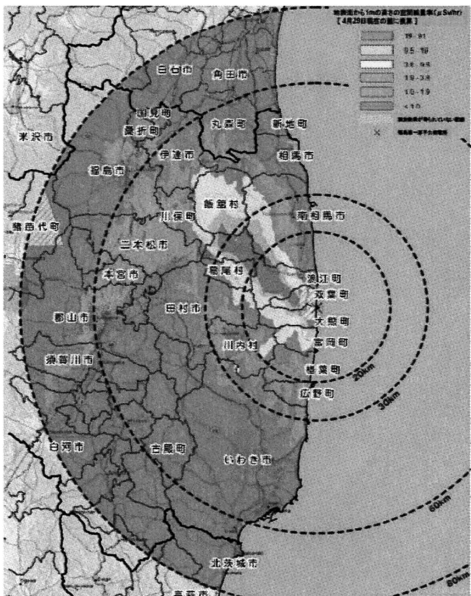

Fig. 1 Spatial dose on April 19, 2011.

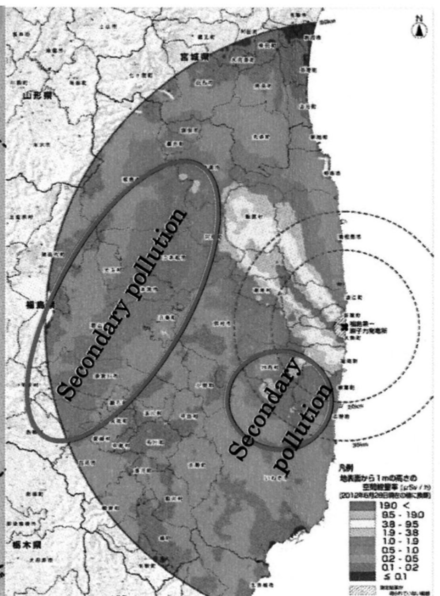

Fig. 2 Spatial dose on June 28.

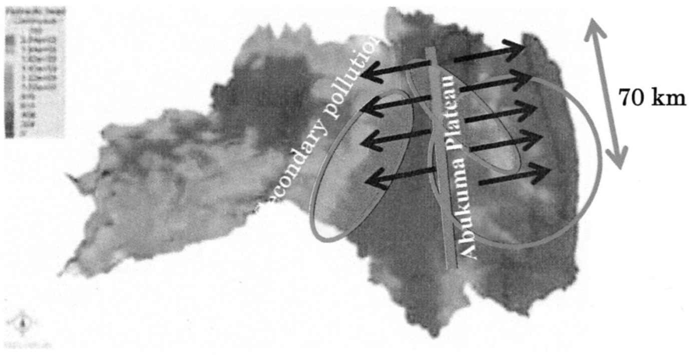

Fig. 3 Water head distribution in Fukushima. From this map, the groundwater around the nuclear power plant is recharged by rainfall over the Abukuma Plateau and flows into the ocean. (Marui, 2012)

(3) Groundwater contamination

Figure 3 shows the distribution of water head in shallow groundwater. As shown in the above, 70% of radioisotopes still remain on the surface of east slope on the Abukuma Plateau in the northwest direction of the nuclear power plant. The rainfall was 1329 mm annually on average. If the recharge area for the groundwater is 334 ha and infiltration water is divided by 90 % for shallow groundwater and 10 % for deep groundwater, daily 5500 m^3 of shallow groundwater could flow under the reactors meltdown. Uranium and plutonium fuel meltdown was estimated by 239 tons and generates contaminated groundwater. On the other hand, on the west slope of the Abukuma Plateau the pollution band with more than 1 μSv/h extends from National Route 114 to Route 4 at present. This pollution becomes the source of the shallow groundwater from Fukushima City to Kohriyama City.

4. DISCUSSION

(1) Future Spatial Dose

At present, dangerous areas with high spatial dose exist more than 1000 km^2 in Fukushima. The areas of 80 km circle from the nuclear power plant have more than 0.1 μSv/h as the national regulation. The total area exceeds 20000 km^2 corresponding to east Fukushima prefecture. Let calculate the date for residents to live safe First, assumed that radioisotopes flow out by runoff ratio 0.3 from the watershed annually. The half-life periods and ratios are assumed as Table 3. As a result, Futaba City would become safe under the regulation in eight years from 2011. In 2019 this city would be safe.

(2) Secondary Pollution and Groundwater

The primary pollution was contaminated by mainly I 131, while the secondary pollution was changed to Cs 134 and Cs 137. Therefore, the primary pollution decreased remarkably, while the secondary pollution decreased slowly. Moreover, the primary pollution occurred over the forest and agricultural fields as land use, while the secondary pollution occurred over urban areas with much population, which means serious effect on Abukuma River watershed.

On the other hand, the groundwater continues contamination by the primary pollution and the leak of radioisotopes from meltdown, and the primary pollution would become 1 μSv/h in 2021. However, pollution by meltdown would continue forever till completion of the removal process for 239 tons of uranium and plutonium. Unfortunately the half-life period of uranium 235 is 703800000 years and the one of plutonium is 24100 years. Therefore, the recovery of the pollution is impossible forever. The amount of contaminated water becomes over 300000 tons.

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