Pollution budget of Fukushima nuclear power plant accident

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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. Hydrospheric pollution was estimated in the watershed for rivers and groundwater pollution by runoff.

METHOD

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: Te132, I131, I132, I133, Cs134, and Cs137.

Water budget was calculated annually as next.

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

where each item unit is mm annually.

Cs 137 dose was calculated by the next equation.

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

RESULTS

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.

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

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. Fig.1 shows the distribution of radioisotopes moving south from Kawamata City to National route 4 (Nuclear Regulation Authority). 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.

Groundwater Contamination

As shown in Fig. 2, the distribution of water head in shallow groundwater (Marui, 2012), 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.

REFERENCES

[1] A. Watanabe, Climate in Fukushima, Journal of Plants in Fukushima, 11, 1987.

[2] Nuclear Regulation Authority, Database on the research of radioactive substances distribution, http://radb.jaea.go.jp/mapdb/

[3] A. Marui, A Wide Area Groundwater Analysis on the Recover from the Earthquake Disaster,GREEN, 18-21, 2012.

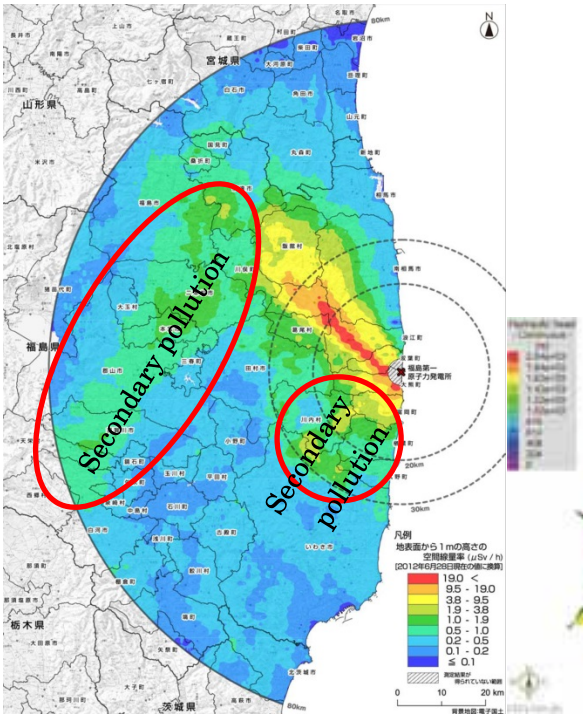

Fig. 1 Spatial dose on June 28, 2012 [2].

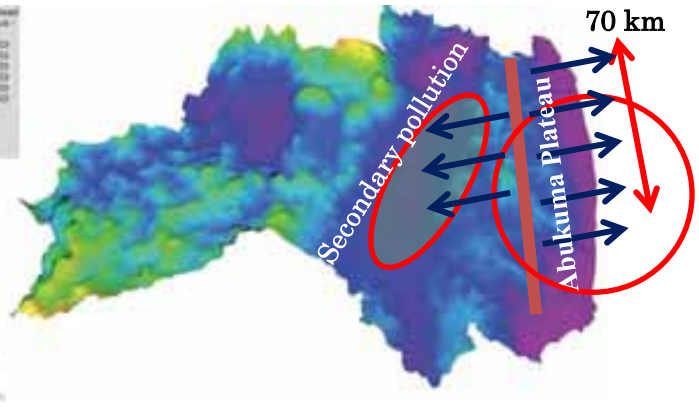

Fig. 2 Water head distribution in Fukushima [3].