NUCLEAR POLLUTION MAP ESTIMATED FROM METEOROLOGICAL DATA

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KEYWORDS: Atomic bomb, Chernobyl, Fukushima, Hiroshima, Nuclear power plant.

ABSTRACT: The most sever nuclear disasters were Hiroshima atomic bomb, Chernobyl and Fukushima nuclear power plant accidents. Pollution patterns were determined by weather conditions, especially wind speed and rainfall intensity. Always wet deposit was superior to dry deposit of radioisotopes. Nuclear pollution maps were made by a particle model with meteorological data. The meteorological data were wind speeds and directions, and rainfall intensity with weather maps in Hiroshima, Chernobyl, and Fukushima. Aero photographs in Hiroshima were taken by B29. A particle model was a simulation for isotope flying over the sky with the horizontal wind speed and the vertical dropping speed calculated by the Stokes equation. From aero photographs, three kinds of wind directions and speeds were estimated. The interviews for eyewitness in Hiroshima were carried out to obtain rainfall intensity and periods with colors. The west part of Hiroshima was polluted by black rain over the Ohta river. From the weather map, cold front was generated near Chernobyl with nimbostratus to bring thunder storms. Two intense pollutions were generated in Belarus and Russia. From the weather data archive, cold air stream flowed over Fukushima at 18:00, Mar 15, 2011. In Hiroshima and Chernobyl, atomic bomb and nuclear power plant might make nimbostratus to bring wet deposit: intense rainfall with much radioisotope.

1. INTRODUCTION

The most sever nuclear disasters were Hiroshima atomic bomb, Chernobyl and Fukushima nuclear power plant accidents. Pollution patterns were determined by weather conditions, especially wind speed and rainfall intensity. Always wet deposit was superior to dry deposit of radioisotopes. Finally, pollution patterns determined health conditions for residents suffered from the accidents. The pollution pattern of Hiroshima was an ellipse figure, while that of Chernobyl was an irregular shape like clouds. That of Fukushima was also an ellipse figure. All rains were thunder storms with very short duration time. However, the pollution areas were quite different: the pollution areas of Hiroshima and Fukushima were very small, 160 km^2 and 630km^2, while the pollution area of Chernobyl was 90000km^2 for severe contaminated area. This difference is very important for nuclear disasters. Two different models were selected for these pollution simulations: an atmospheric dispersion model and a particle model. Nuclear pollution maps were made by these models with meteorological data. The severe pollution time for these disasters was estimated by the simulations.

2. METHODS

2.1 Aero photographs

Aero photographs in Hiroshima were taken by B29 at 9:15, Aug 6, 1945. Most of the pictures were still not open for the public. This picture was only one to present “black rain” as shown in Figure 1.

2.2 Meteorological data

The meteorological data were wind speeds and directions, and rainfall intensity. The weather maps in Hiroshima, Chernobyl, and Fukushima as shown in Figures 2 to 6. Radar rain maps were used for Fukushima as shown in Figures 7 and 8.

Figure 1. Aerial photo in Hiroshima, 1945.

Figure 2. Weather map in Japan, 9:00, Aug 6.

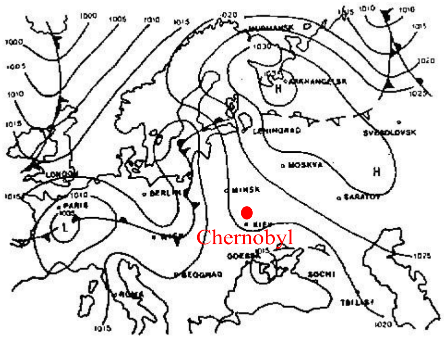


Figure 3. Weather map in Europe, 4:00, Apr 26.

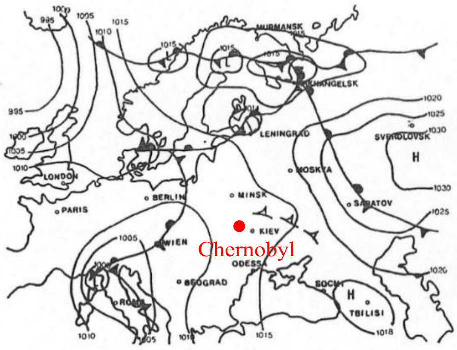


Figure 4. Weather map in Europe, 4:00, Apr 28.

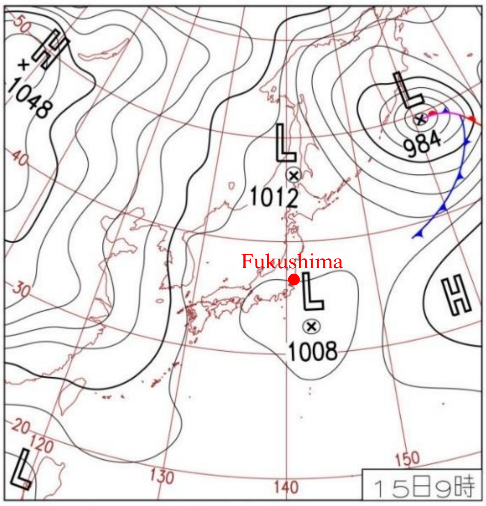


Figure 5. Weather map in Japan, Mar 15.

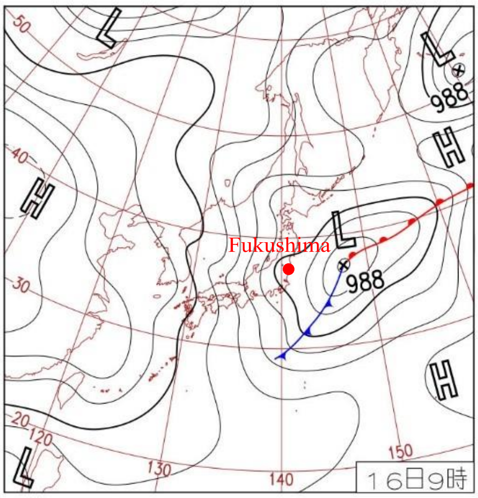
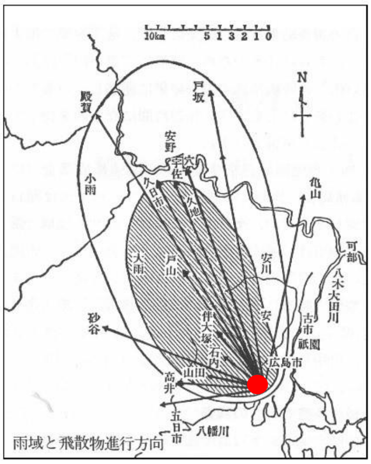


Figure 6. Weather map in Japan, Mar 16

Figure 7. Radar map, 23:00, Mar 15, Fukushima.   Figure 8. Radar map, 23:20, Mar 15, Fukushima.

2.2 Pollution maps

A pollution map in Hiroshima was made by Japan meteorological agency. Dr. Michitaka Uda was exposed to radiation, but started to research with five members immediately (Science Council of Japan, 1953). The sample number by the interview was 116: 68 samples for rainfall and 31 for black rain as shown in Figure 9. A pollution map in Chernobyl was made by UNSCEAR: United Nations Scientific Committee on the Effects of Atomic Radiation (2000) as shown in Figure 10.
A pollution map in Fukushima was made by U.S. Department of Energy as shown in Figure 11.



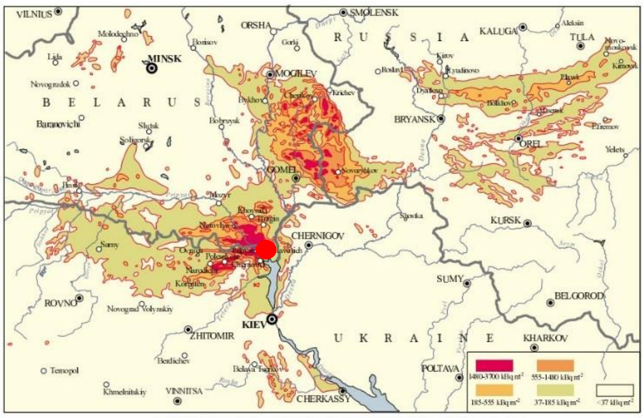


Figure VI. Surface ground deposition of caesium-137 released in the Chernobyl accident [11,13].

Figure 9. Black rain map in Hiroshima, 1945.   Figure 10. Pollution map in Chernobyl, 1986.

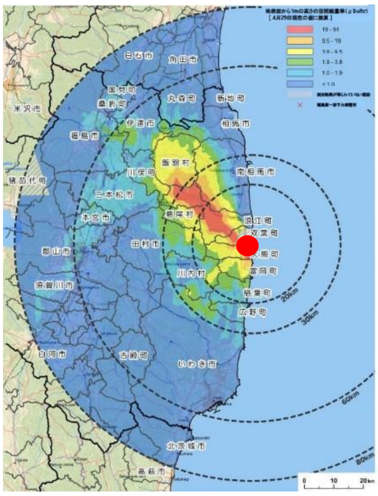
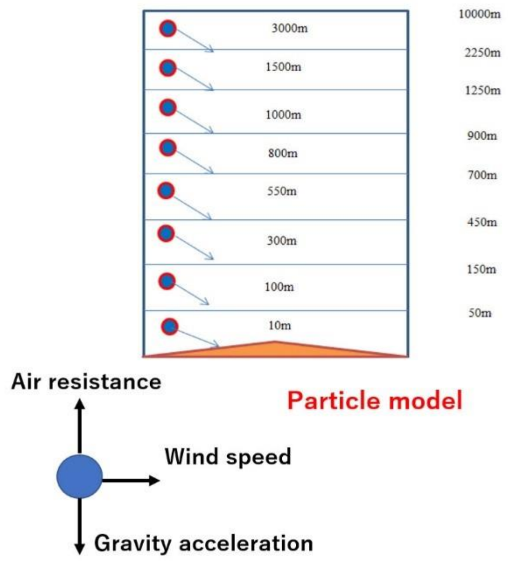


Figure 11. Pollution map in Fukushima, Mar 22, 2011.

2.3 Pollution models

A particle model was a simulation for isotope flying over the sky with the horizontal wind speed and the vertical dropping speed calculated by the Stokes equation. Therefore, the particle flying trajectory was determined with wind speed and direction data each particle size and the initial height as shown in Figure 12. Another model was the atmospheric dispersion model as shown in Figure 13.



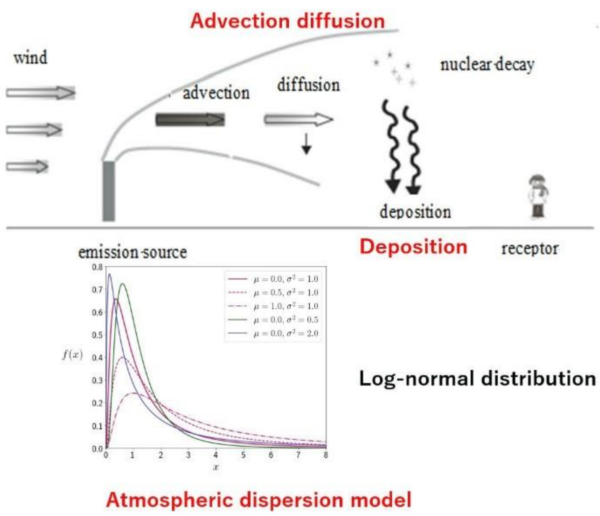
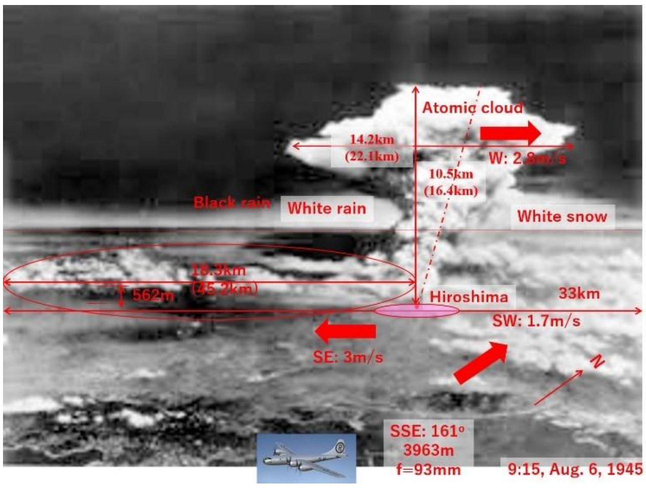


Figure 12 Particle model simulation   Figure 13 Atmospheric dispersion model simulation

3. RESULTS

3.1 Hiroshima atomic bomb

From aero photographs at 9:15, three kinds of wind directions and speeds were estimated as shown in Figure 14: Atomic cloud was *cumulonimbus* to east with 10.5km height and 14.2km wide in wet deposit, black rain was *nimbostratus* to north west with 562m at the cloud base and 18.3km wide in wet deposit, and *cumulus* independent from atomic bomb moved to north east in dry deposit. Three kinds of pollutions occurred each cloud: white rain from atomic cloud, black rain from thunder storm generated by local heat, and white crystal and amorphous in radioisotopes.
The interviews for eyewitness in Hiroshima were carried out to obtain rainfall intensity and periods with colors. The intense rain area was 164km^2 with 19km of major axis and 11km of minor axis as shown in Figure 9. The rainfall intense was estimated by 50mm/h. The weak rain area was 341 km^2 with 29km of major axis and 15km of minor axis. The rainfall intense was estimated by a few mm/h. The west part of Hiroshima was polluted by black rain over the Ohta river. Thus, people in Hiroshima had drunk contaminated water from the water source: the ground water and the Ohta river.
Wet and dry deposits were calculated by a particle model as shown in Figure 16. Hibakusha was defined by Uda pollution estimates as shown in Figure 9, but real hibakusha was more than them.



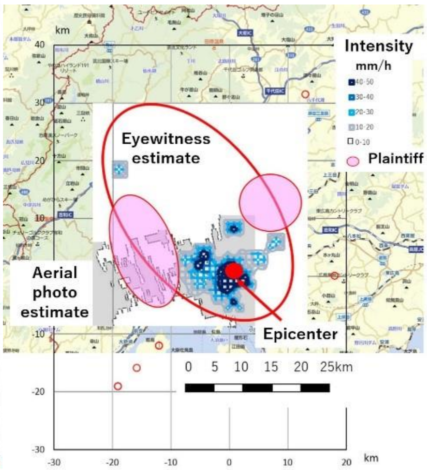


Figure 14. Aerial photograph by Enola Gay. Figure 15. Pollution estimate

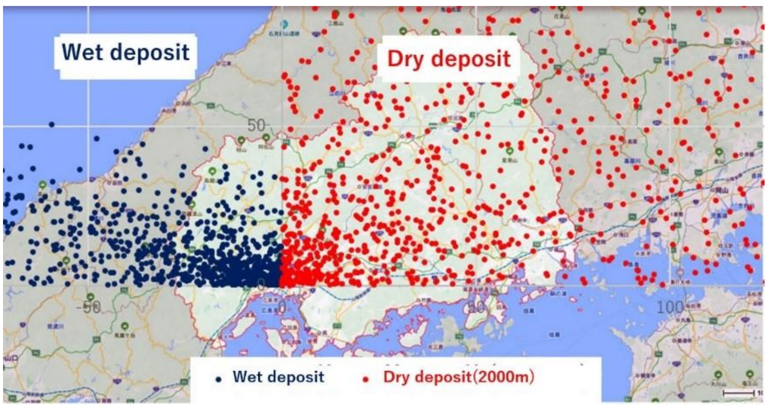
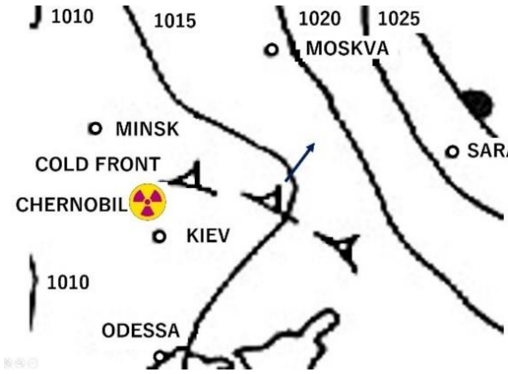


Figure 16 Wet and dry deposit simulations in Hiroshima

3.2 Chernobyl nuclear power plant

From the weather map in Figure 3, the east wind blew with 2.4 m/s on average and partially south wind blew in three hours on Apr 26, then radioisotope polluted about 200km west from Chernobyl in dry deposit. On Apr 27 the wind was weak with 1.6m/s on average, then radioisotope polluted isotropically 140km from Chernobyl in dry deposit.

From the weather map in Figure 4, cold front was generated near Chernobyl by the power plant accident with nimbostratus to bring thunder storms as shown in Figures 17 and 18. Two intense pollutions were generated in Belarus and Russia with cold front. The first cold front was generated near Gomel 3:00 on Apr 28 with intense rainfall while the second cold front was generated near Bryansk at 6:00 on Apr 28 in Figure 18. The first storm was 15mm at Slavgorod near Mogilyov at 3:00 to 6:00. The second storm a few mm near Bryansk at 6:00 to 12:00. These storms were deterministic to radioisotope pollution in Chernobyl. A particle model showed the total pollution in dry and wet deposit in Figure 19. The winds at 1000m and 1500m were estimated by power-law scaling with power 1/7. The serious pollution was northeast part with 200 to 300km from Chernobyl.



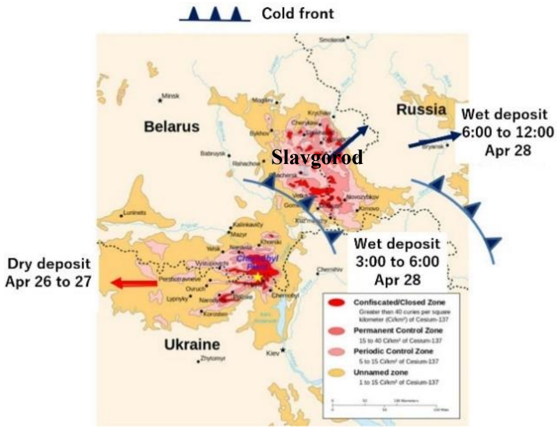


Figure 17. Weather map in Chernobyl Figure 18. Cold front with storms

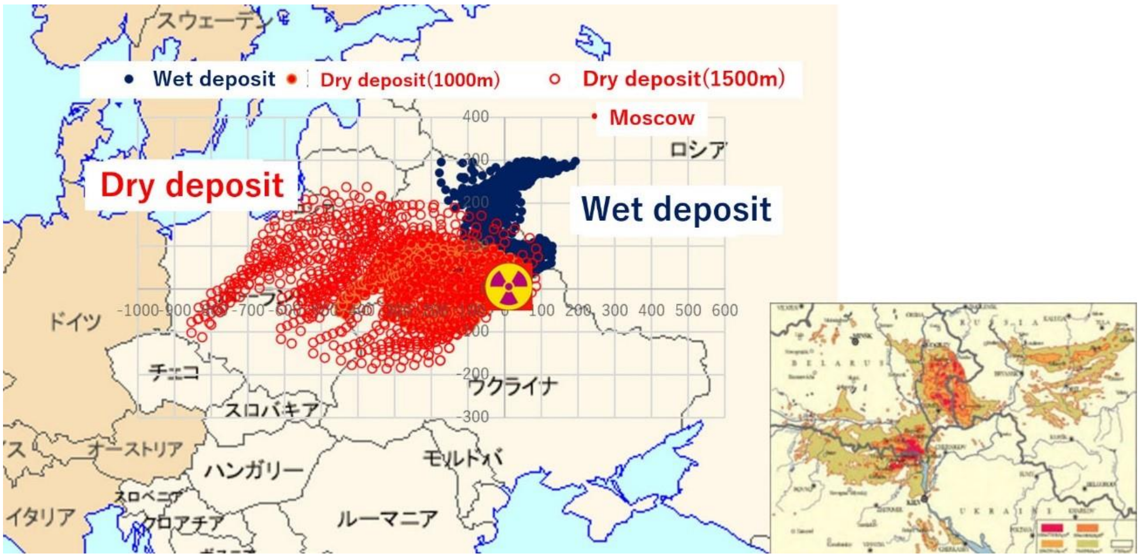


Figure 19. Wet and dry deposit simulations in Chernobyl.

3.3 Fukushima nuclear power plant

Fukushima Daiichi nuclear power plant had five times explosions, among them southeast wind blew only at 15:36 to 17:00 on Mar 12 and at 20:00 to 24:00 on Mar 15. The rainfall occurred at night on March 15. From Figures 5 and 6, the cold front was generated and passed over Fukushima at 23:00 on Mar 15. From Figures 7 and 8, the intense rain occurred with 10mm/h at 23:00 to 23:40 on Mar 15. Therefore, the serious radioisotope pollution was in wet deposit in Fukushima.

A particle model showed this serious pollution in Figure 20. Finally wet deposit and dry deposit were interposed on the way from the nuclear power plant and Fukushima city. Water sources over Abukuma hills were completely polluted, but people drink polluted water still now. This situation is the same as Hiroshima and Chrnobyl.

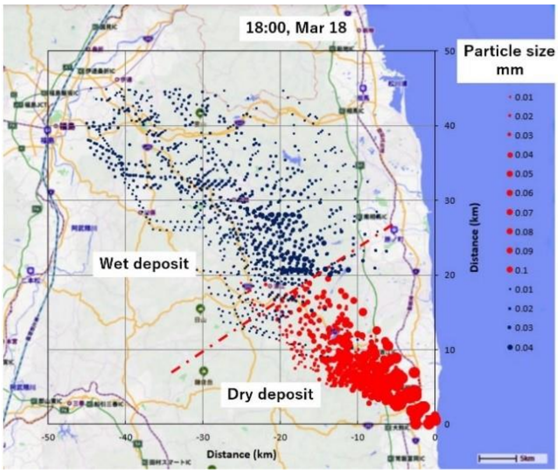


Figure 20. Particle model simulation in Fukushima

4 DISCUSSION

4.1 Cold front and thunder storms

Cold front generates *cumulonimbus* and *nimbostratus*, which bring thunder storms. Cold front moves to east in the north hemisphere. The intense rain clouds move over the cold front. On the other hand, atomic clouds move in local wind directions. The collision between them becomes wet deposit: serious pollution. In Hiroshima, serious pollution occurred at 8:15 to 9:30 on Aug 6, 1945. In Chernobyl, serious pollution occurred at 3:00 to 6:00 on Apr 28, 1986. In Fukushima, serious pollution occurred at 23:00 to 23:40 on Mar 15, 2011. The thunder storms continued within one hour each. In Hiroshima, the rain intensity was 10 to 50 mm/h. In Chernobyl, the rain intensity was 15 mm/h. In Fukushima, the rain intensity was 10 mm/h. Then, the shape of pollutions was affected by cloud shapes. However, in Hiroshima and Fukushima, the effect of mountains was dominant to clouds. Therefore, in Chernobyl, the shape of the pollution was similar to clouds, while in Hiroshima and Fukushima, the shape of the pollutions was similar to the watershed boundary.

4.2 Atomic explosion and local low pressure

In Hiroshima and Chernobyl, atomic explosions occurred and made thunder storms. The explosions made much heat and vapor to generate local low pressures. Moreover, in Chernobyl, enormous heat made cold front, and in Hiroshima, enormous heat made *cumulonimbus* and *nimbostratus*. Atomic explosions broke local weather.

5 CONCLUSIONS

Dry deposit brings isotope pollution isotropically. Pollution intensity was inversely proportional to the distance of the source and depended on topography.
Wet deposit brings isotope pollution discontinuously by rain clouds. Pollution intensity was proportional to rain intensity. The distribution shape was similar to rain clouds. But in Hiroshima and Fukushima, the shape was similar to the watershed boundary.
Wet deposit was more than two times as much as dry deposit in intensity.
Atomic bombs and nuclear power plant accidents made low pressure with cold front and nimbostratus clouds.

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