Appendix II

This Appendix II is a translation from a report published in 1947 by M. Uda. We, Hiroshima City with M. Aoyama, translate only chapter 1, 2 and 5 of the report. The original report is written in Japanese entitled "廣島原子爆弾被害調査報告 : 氣象関係 Meteorological Conditions Relating to the Atomic Bomb Explosion in Hiroshima City（Synopsis）" and is in a collection at National Diet Library Japan with a book ID 000010975667. This report is also in a collection at Hiroshima Peace Memorial Museum.

Meteorological Conditions Relating to the Atomic Bomb Explosion in Hiroshima City (Synopsis) by Mititaka Uda
Nov. 1947
The Hiroshima District Central Meteorological Observatory

Contents

1. Introduction
This report is a summary drafted by Mititaka Uda, the Chief Technical Officer of Kobe Marine Observatory, based on research results conducted by Yoshio Sugawara, Head of the Hiroshima District Central Meteorological Observatory and staff members of the Observatory, Isao Kita, Masahiro Yamane, Kiyoyuki Nakane, and Munetaka Nishida during the period from August to December in 1945.

This meteorological research was conducted as an activity of Subcommittee 1 Team C belonging to the Atomic Bomb Damage Research Committee of Science Council of Japan to reveal the meteorological aspects relating to the atomic bomb explosion.

In November 1947, it was decided that this report should be published and distributed to interested bodies.

2. The state of things at the Time of the Explosion
The following facts were discovered from a survey of people who had experienced the atomic bombing in Hiroshima. Within a 2 km radius of the hypocenter, immediately after a flash of light of the explosion was seen, buildings and earthen walls collapsed and dust rose up everywhere in a moment as like black smoke, suddenly throwing the surroundings into darkness comparable to that of dusk or a solar eclipse. It took 5 to 30 minutes before the smoke cleared and get back the light.** (Those people who were directly under the epicenter saw white flashes of light about a foot in width across falling and as if numerous large meteors had hit, and then felt that several hundred bombs were detonating near the ground.

** *In Hiroshima, people who inhaled the "gas" are often said to suffer more severely from the A-bomb disease. This "gas" probably refers to the black smoke that rose upwards, which contained highly radioactive toxic substances. Many of those who were within the 2 to 5 km radius of the hypocenter and who had been in a location where there was a wide view, such as mountain tops, arena or open fields, observed the fireball explosion in Figure 1 a, b and c mentioned above.*

Those who were farther away 5 km from the hypocenter could have time to observe a gigantic column of clouds rise up and change in shape. They were also able to clearly identify that there was a time lag between the flash of light and the blast.

Therefore, when the explosion occurred and almost simultaneously with the spread of fire and light, pillars of black smoke of dust rose up from the area within 2 km of the city center and covered the atmosphere above the entire city. The shower subsequently occurred washed out the dust downwards and resulted in black rain that fell to the west of the city, while the black smoke of dust that was not washed out was transported by wind field and became fallout of black dust.

What mechanism made such black dust to sudden rise? It seems most likely that the explosion itself and the resultant high heat flux made the gas and air near the epicenter to expand suddenly. The blast of the explosion hit the ground surface and then the dust from the collapse of houses, earthen and other walls and the particle materials from the bomb itself including radioactive materials were mixed in, like a cloud of ashes dancing upwards. Then, the air in the epicenter rose quickly due to buoyancy of low density of the air followed by the black smoke rise up into the atmosphere as a low pressure suction effect. It took only several seconds after the flash of light.

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5. Shower caused by the Bombing and Urban Fire

On June 1st in Osaka, the rain was black, due to smoke and soot being mixed in rainwater. Muddy dust adhered onto helmets and clothing. The bombing raid occurred from around 9:40 to 11:30 hrs. Fires ensued in numerous successions. At about 13:00, the fires were at their most fierce and lasted into the evening. The rain fell from 11:48 to 16:37 hrs. From 11:23 to 12:19 hrs, the rain was accompanied by thunder (information by courtesy of Mr. Kunitomi, Head of the Osaka District Central Meteorological Observatory).

In Hiroshima, the shower occurred came down with great intensity in some areas and was relatively widespread. It covered an oval domain with longer axis 19 km and minor axis 11 km where the shower continued one hour or more. For light rain areas, it was also an oval domain, with longer axis 29 km and minor axis 15 km. (See Figure 4)

What is more, this rainwater was not only black and muddy but its muddy dust had high radioactivity, causing toxic physiological effects on humans such as hair loss and diarrhea. Other phenomena were observed, including the floating of dying fish. It became a significant factor in retaining high radioactivity in the soil of the western areas of Hiroshima for a long time up to two to three months after the explosion.

In Nagasaki, which was also attacked by an atomic bomb, only a small scale shower occurred in comparison to Hiroshima. This is probably due to the lack of a weather front as was the case in Hiroshima and to the urban fires after the explosion being much smaller. These were most likely the major factors in the general meteorological conditions that created rainfall.

Thus, the shower generated by the bombing and the precipitation mechanisms in particular may be well worthy of research from the perspective of technology of artificial precipitation and will shed great light on future investigations.

Rainfall Conditions

A. The area of precipitation (See Figure 4) started from near the epicenter in Hiroshima City and formed an oval stretching mainly over the northwestern area of Hiroshima City and extending to the hills to the northwest right up to Yamagata-gun. Figure 2 shows a more detailed and enlarged view of the affected area focusing on Hiroshima City and its environs.

B. Figure 5 shows the distribution of precipitation at the beginning

The time of begin of rainfall ranged from 15 minutes to 4 hours after the flash of nuclear explosion but many of the rainfall started between 20 minutes to an hour after the flash. In a front area, rain started more than 1 hour to 2 hours after the flash (in Hakushima, 4 hours after the flash). This was probably caused by the development of convergent upward motion caused by the urban fires.

In short, this precipitation resulted as a combination of precipitation caused by the direct upward motion caused by the explosion and the precipitation caused by the indirect effect of the upward motion caused by urban fires that ensued from the explosion. They were strengthened by the presence of the weather front.

C. Period of Precipitation* (See Figure 6 and Figure 4)

Areas of several minutes and less than 30 minutes precipitation were classed as “small rainfall areas,” areas of heavy rainfall of more than 30 minutes and up to 1 hour were classed as “medium rainfall areas,” areas of rainfall of 1 and up to 2 hours were classed as “heavy rainfall areas” and areas of torrential rainfall of 2 or more hours were classed as “torrential rainfall areas” as shown in Figure 6.

The areas affected by shower were of oval shape, stretching from Hakushima to Misasa, Yokogawa, Yamate, Hirose and Fukushima-cho, through to Koi-machi, Takasu and beyond Ishiuchi-mura and Tomo-mura and finishing in Toyama and Kuchi-mura.

** As the duration of rainfall (t minutes) increases, the precipitation amount (r mm) obviously increases. The correlation between the duration and precipitation amount according to Köppen is expressed using a formula*

$r=n\sqrt{t}$ *(n=8 in Germany),*

and the intensity of the rain by the formula

$i=n/\sqrt{t}$.

D. The Time of End of Rainfall (See Figure 7)

The ending of rainfall began from 9:00JST to 9:30JST that day and extended to 15:00JST to 16:00JST. The rain stopped by evening but the ending was staggered, moving away from the epicenter to the northwest. This is different in distribution to the start of rain. However, along the front line, a protruding tongue-shaped area of delayed ending is seen.

E. Bias in Precipitation Distribution

(i) Looking at all the distributions of the areas of precipitation (See Figure 2 and Figure 4), the period of precipitation (See Figure 6 and Figure 4), start time of rainfall (Figure 5) and end time of rainfall (Figure7), there is a pronounced bias to the north along the line drawn in the northwesterly direction from the epicenter, with a special distribution that appears to exist, the front line being its axis. Concentric upward motion caused by the explosion and fire were created in the sky chiefly above the hypocenter. These upward motion were transported to the northwest by general wind field and enhanced by precipitation resulted, as well as being strengthened by precipitation due to continuous upward motion at the weather fronts.

(ii) The mountain slopes facing the explosion, namely, the southeasterly slopes of the mountain range from Takedayama, Yamate, Chausuyama, and Koiyama to Onishiroyama lying behind the north of Furue, the southeasterly slopes of the northern mountain range of Ishiuchi-mura, Tomo-mura and Yasu-mura, and the southeastern slopes of the mountains in Toyama-mura and Kuchi-mura had relatively large amounts of precipitation. The areas of these mountains on the other side, in other words, the northwestern slopes, had relatively little precipitation.

Properties of the Rain Water

A. Black Rain (Muddy Rain)

(i) The raindrops of the small rain at the start of rainfall contained a great deal of black muddy substance, making them sticky in consistency. At the time, people worried that "oil was poured down" but the raindrops did not have any odor and were not like oil. However, white clothing became splashed with black dirt or bamboo leaves became smeared in streaks.

(ii) The river runoff of black rain in the Tani-gawa River foamed white. The water of the river was black, as if Japanese Sumi-ink had been dissolved in it.

(iii) Large raindrops like hailstones fell in torrents, in large drops that felt painful on bare skin.

(iv) When the heavy rain fell, despite being a hot day in the height of summer, the temperature dropped sharply. Many people had fled with little or no clothing and were shivering.

(v) The muddy substance* in the rainwater, according to the research findings of Mr. Sasaki and Mr. Miyazaki of the Riken Survey Team, was extremely high radioactive and even two months after the explosion, measured radiation was 50 Nat. which was several times greater than that in the hypocenter.

** The muddy substance above was collected from the mud that had adhered to the wooden shutter (which had been thrown out into the garden by the blast of the explosion and was hit by rain) of the author's house in Takasu. The author's second son who returned home from his school's evacuation site in the remote mountains had slept next to the wooden shutter and found his hair falling out. Alarmed by this, the wooden shutter was removed.*

(vi) Fish, such as carp in the pond and abalone and eel in the river died and floated up to the surface because of the black rainwater.

(vii) Cattle that ate the grass that had been rained on by the contaminated water had diarrhea.**

*** A high number of people in Koi and Takasu areas were affected by diarrhea even three months after the explosion. The cause of this is conjectured to be their drinking water from the well (ground water) as water supply pipes had been destroyed.*

B. Clear Rain and the Mud Itself

After the black rain had fallen for 1 to 2 hours, ordinary clear rain followed. The muddy substances dispersed in the atmosphere seemed to have consisted mainly of muddy dust that rose up as black smoke at the time of the explosion and the smoke dust due to the urban fire, which were mixed with radioactive matter and dust of substances originating in the explosion that were floating in the air or had once fallen onto the ground.

Indeed, muddy substances that had adhered onto the above-mentioned wooden shutter due to black rain were collected and examined by dispersing in water. It was readily discovered that its main constituent was a mixture of the black and fine mud dust that normally exist in the Hiroshima City area and the brown sandy mud dust of the slightly rough-grained eroded granite from farmland and hill areas nearby. Conjecturing from this, the muddy smoke dust that rose up in the air and were floating there had been washed out and the rain turned clear, which means that until then, the rain was black due to contamination. In other words, the dust particles in the atmosphere were mostly removed by the washing down of rainwater in 1 to 2 hours and they fell to the ground. Therefore, areas where precipitation was heavy, namely Takasu and Koi areas in the western areas of Hiroshima City, probably came to measure high in radioactivity.

C. How the Rain Fell

In many cases in torrential rain areas, the rain started at first as scattered showers, then became heavy for 30 minutes to 1 hour, after which there was a lull and then heavy rain resumed. The rain was undulating, with the initial heavy rain being black rain and the later heavy rain being clear rain in many cases.

Estimated Precipitation Amount

Regrettably, there were no meteorological stations in these areas of precipitation. Therefore, we are unable to quantify the precipitation amount. However, in the Tani-gawa River of Koi and the Yasu-gawa River of Tomo-mura and Yasu-mura that flow through these villages, almost the same amount of water flow was seen in a short period as was the case in the typhoon of September 17 and 18* and from this observation, we can conclude that there was 50 to 100 mm of precipitation in the 1 to 3 hour period in the areas of torrential rain.

By W. Köppen's formula, ** amount of heavy rainfall (mm) =n√period of continuous rain (minute). For 1 to 3 hours of continuous rainfall period, total amount of rainfall becomes 60 to 110 mm. This corresponds roughly with the estimate given above. Therefore, the total rainfall of the areas of rain discussed is estimated to be 140,000 m^3 to 240,000 m^3.

This heavy rain totally extinguished the forest fires in the Koi and Yamate areas.

* Total rainfall was nearly 200 mm. The rain fell over two days and assuming the flow rate from surface rainwater into river as roughly 1/2, the equivalent rainfall was estimated to be between 50 and 100 mm.

** See Takematsu OKADA, *Ame* (Rain), 1916.

Precipitation Mechanism

Given that the precipitation mechanism of the rain ensuing the explosion was remarkably intense and continuous of torrential rainfall, the author considers that it was different from precipitation that would have arisen simply from strong upward motion due to the explosion and urban fire. Added to these factors, there would have been the release of ionizing radiation (i.e. β rays or neutrons) of fission products from the detonation of the atomic bomb, such as happened in a giant Wilson chamber, the dust in the atmosphere was ionized continuously into numerous ions, which became cloud condensation nuclei and floated in the atmosphere, triggering heavy precipitation.

In order to fully understand such a phenomenon of heavy shower, research must surely be conducted by adding a new knowledge of nuclear physics to the conventional geophysical approach. Another future topic of research will be the consideration of incorporating the action of radioactive materials into the technology of artificial precipitation.

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