RERF's Views on Residual Radiation

8 December 2012
Radiation Effects Research Foundation

Introduction

Analyses of radiation doses from the atomic bombs dropped on Hiroshima and Nagasaki that have been conducted by the Radiation Effects Research Foundation (RERF) and many other researchers have shown that involvement of residual radiation is within the range of error in terms of initial radiation dose estimates. Although RERF has published and explained these results over many years, criticism and doubts continue to arise that no consideration has been given to data on residual radiation. This report aims to clarify misunderstandings and to provide everyone with accurate knowledge.

Since the mass media's first reporting of the Yamada-Jones report (Oak Ridge National Laboratory Report, ORNL-TM-4017, 1972) in 2011, the "black rain" issue has again attracted the attention of the public. As a result, various news articles on this issue have appeared, and some are not necessarily correct, one example of which was a media report that confused "residual radiation exposure" with "internal exposure." A recent television program implied that RERF's risk data were useless because radiation doses used for radiation risk analysis did not include residual radiation. We are concerned that, if the present situation continues, RERF's research analyses, which provide the scientific basis for radiation risk assessment and radiation protection standards throughout the world, may be grossly misunderstood, leading to unnecessary worries among the public, including A-bomb survivors. We, therefore, would like to restate in this report RERF's views and information on such issues.

Exposure to A-bomb radiation

There were two types of exposures to A-bomb radiation: one was exposure to "initial radiation" released at the time of the detonations of the bombs, and the other was exposure to "residual radiation," which happened later. Initial radiation mainly consisted of neutrons and gamma rays emitted from the explosions to which people were exposed within a few seconds when such radiation reached the body's surface (external exposure). Doses from direct exposure to the initial radiation were determined on the basis of attenuation due to three factors: distance from the hypocenter (the point on the ground directly below the bomb detonation), shielding from such objects as buildings or hills, and shielding from intervening tissues inside the body before radiation reached a particular organ, which depended on body positioning at the time of exposure in relation to the direction of the radiation's advance. Availability of information on the aforementioned three factors makes it possible to calculate organ dose estimates for individual A-bomb survivors.

On the other hand, "residual radiation" was secondary radiation resulting from radioactive materials that remained in the environment from the nuclear detonations. This type of radiation can further be classified into induced radiation and fallout radiation from radioactive substances scattered in the air. Induced radiation was caused by temporary activation by the neutrons in the atoms making up certain substances in the metals of some buildings and in soil. Most of the exposure to induced radiation, excluding exceptional cases of fine particle inhalation, was external, and most of the induced radioactivity decreased rapidly with time after the bombings. On the other hand, the remaining A-bomb source materials and secondary radioactive materials generated by the nuclear detonations rose high in the air with the fireballs and were widely scattered in the atmosphere. A portion of the radioactive particles suspended in the air gradually fell to the ground, with such movement accelerated by rain and other forms of precipitation. So-called "black rain" is thought to have contained such radioactive fallout. The cause of the black color of the rain was actually soot from the secondary fires, and therefore the rain's color was not directly indicative of the level of radioactivity. The possibility exists that even the rain falling soon after the explosions that was not black might have contained radioactive substances, and some that was black had essentially no radioactivity.

With regard to these particles, we need to consider both "external exposure" from radioactive substances that remained in the air or that fell to and accumulated on the ground and "internal exposure," which was caused by direct inhalation of particles remaining in the air and by intake of radioactive substances reaching the ground and into the body by way of various pathways. Pathways of "internal exposure" included direct intake of radioactive fallout on the ground mixed in with drinking water and vegetables and intake of radiation that was re-concentrated in milk from cows (or goats) feeding on grasses contaminated by radioactive fallout (principally applicable to radioactive iodine).

As described above, calculation of individual doses from initial radiation is possible, but estimation of individual doses from residual radiation is far more complicated, with acquisition of information required for accurate estimation exceedingly difficult.

With regard to induced radiation, because temporal and geographical distributions of radiation in the environment are generally known due to actual measurements and complementary calculations, individual radiation doses can be estimated in principle. For such estimation, however, it is essential to obtain accurate records on individual behavior and activity by times concerning their location and duration of stay until about one week after the A-bombings. However, it is impossible to obtain information of a certain quality for the entire subject population to create dose estimates of adequate quality that would allow epidemiological estimates of possible radiation health effects.

Next, with regard to radioactive fallout, the geographical distribution was not uniform, and movement of fallout due to wind and/or water runoff after it had reached the ground makes such distribution more complex. Therefore, except for some measured cases, little is known about the geographical distribution of fallout radiation by elapsed time, further complicating the estimation of radiation doses. It is not an exaggeration to conclude that the estimation of amounts of inhalation of radioactive substances in the air and of intake from food and drink (internal exposure dose) is nearly impossible.

Therefore, the only methods for estimation of "internal exposure" are measurements using whole-body counters and such biological monitoring as chromosome tests and measurements of tooth enamel by electronic spin resonance. These tests, however, have limitations relevant to time after exposure. As for biological monitoring, for example, sample collection is possible only while the survivors are still alive, and exposure to doses of 200 mSv or lower is undetectable. Moreover, in biological monitoring, evaluation can only be made of the total of both external and internal cumulative exposure doses.

Effects of residual radiation dose on risk evaluation of A-bomb radiation

RERF has been releasing over the years radiation-risk information that shows associations between radiation dose and frequency of cancer development (death) based on its

Life Span Study of 120,000 people, including about 94,000 A-bomb survivors. These data have been given high marks internationally, and are used as the basic data for establishment of radiation protection standards. For these risk calculations, only doses from initial radiation have been used. If the residual radiation exposures had been large, then the reliability of these risk data would have decreased in proportion to the amount of unknown residual radiation levels. As stated below, however, there is reason to believe that the effects of residual radiation were low enough to be considered virtually negligible.

1) Many scientists, including RERF researchers, have worked on analyses of radiation doses from the A-bombs dropped on Hiroshima and Nagasaki. In particular, Chapter 6 of the Dosimetry System 1986 (DS86) report summarizes the results of area radiation surveys that were conducted within several years after the A-bombings. Most were conducted from August through November of 1945, and some were conducted before the two typhoons that devastated Hiroshima in the autumn of that year. A major importance of these studies lies in the fact that the measurements were made before later nuclear tests were conducted in various parts of the world that so highly contaminated the entire planet with radioactive fallout that it was then very difficult or impossible to accurately measure amounts of residual radiation from the 1945 bombs. But such studies have indicated that the residual radiation levels were nearly so small as to fall within the estimated range of error of the initial radiation doses.

2) With regard to induced radiation, as mentioned above, the geographical distribution of radiation dose by elapsed time after the A-bombings is known. Thus, simulation of radiation doses has been performed, assuming various circumstances concerning individual behavior and activity immediately after the A-bombings. The following table provides dose estimates for early entrants into areas near the bombing hypocenters. The table shows that a person would have had to spend a considerable amount of time very close to either of the hypocenters within the first several days after the bombings in order to acquire a meaningful dose. As an example, if someone had stayed at a distance of 500 m from one of the hypocenters for 12 hours on the day following the A-bombing, the induced radiation doses would have been about 15 mSv in Hiroshima and 3 mSv in Nagasaki. On the other hand, if a person had stayed at a distance of about 1000 m, the doses would have been inconsequential.

Potential Exposures of Early Entrants, Hiroshima and Nagasaki

	Distance from Hypocenter and Estimated Colon Doses (mSv)				
Time of Entry [A]	200m	500m	700m	1000m	1500m
Hiroshima					
Day 2 [B]	82	15	3	<0.5	<0.5
Day 3	40	8	2	<0.5	<0.5
Nagasaki					
Day 2	18	3	1	<0.5	<0.5
Day 3	9	1	<0.5	<0.5	<0.5

[A] The table dose estimates assume that a person arrived at the indicated distance from the hypocenter at 6:15 AM and stayed at that distance for a full 12 hours. (The dose would be approximately proportional to the amount of time spent at that location.)

[B] Day 2 is the day after the bombing, day 3 is the next day. For days 4, 5, etc., not indicated in the table, the dose levels for each successive day decrease by approximately 50% from the previous day.

3) One report produced by NHK shows a study of Japanese Kahoku military troops that is one example of an investigation into a group of people with a history of exposure to residual radiation. These special duty troops consisted of about 250 reservists who had been gathered from Higashi-Hiroshima City for such relief activities as clean-up of rubble from near the hypocenter starting August 7, the day following the A-bombing, until August 13. For a unit of 99 of the reservists for whom precise behavior and activity records during that period were maintained, Hiroshima University, RERF, and other institutions calculated radiation dose estimates. The estimates showed that most of the unit's radiation exposure was from induced radiation, that the estimated maximum dose was 100 mSv based on both chromosome aberration frequencies and computer simulations, and that the average dose for the entire unit was 13 mSv. Moreover, in a mortality study of these 99 people conducted over a period of 42 years since August 1945, no difference was observed in either all causes of death or cancers when compared with national averages.

4) Other examples of studies on residual radiation exposure include a study of cause of death among early entrants into the cities conducted as part of the Life Span Study. This study on cause of death was conducted from 1950 to 1978 on 4,512 people who had entered the cities of Hiroshima and Nagasaki within one month after the A-bombings. No evidence of a mortality increase (due to either all causes of death or cancers) was observed in the study. In view of the fact that people could not approach the area near the hypocenter because of secondary fires on the day of the A-bombings, the radiation doses of the abovementioned Kahoku troops are considered to be the maximum plausible levels of residual radiation exposure.

5) Studies concerning internal exposure include those conducted in 1969, 1970, and 1971 on subjects in the Nishiyama district of Nagasaki, where the amount of radioactive fallout was the largest of any location in either Nagasaki or Hiroshima. Interviews were first conducted of residents whose radiation doses were considered to be the highest in this district, and then the 50 residents whose internal exposure doses were estimated to be the highest among the interviewed residents due to their intake of local vegetables and drinking water were selected as subjects. It was shown as a result of measurements of internal exposure doses (cesium-137: the principal isotope, with a long half-life of 30 years) by whole-body counter that the cumulative exposure doses during the 40 years from 1945 to 1985 were estimated to be 100µSv (i.e., 0.1 mSv) among males and 80µSv among females. Those cumulative doses were calculated on the basis of a half-life of 7.4 years, which was inferred from additional measurements conducted on a portion of the relevant population in 1981. Those low levels (i.e. 100 and 80 μ Sv) represent only about 1/1000 of the accumulated 40-year global background radiation dose (based on 40 times the annual dose that was announced by the World Health Organization (WHO)).

As mentioned above, only estimates of initial radiation doses are used for calculation of radiation risks at RERF, but error of about 35% is considered to exist in individual dose estimates based on the Dosimetry System 2002 (DS02). The major reason for the uncertainty is thought to be erroneous or imprecise information obtained from interviews conducted in the early location/shielding studies for radiation dose estimation.

RERF's risk evaluations of cancer incidence and mortality from A-bomb radiation depend largely on the fact that risk estimates among people exposed to such high doses as 1-4 Gy show clear radiation dose response. Therefore, even inclusion of a moderate number of people exposed to estimated residual radiation doses of about 10-100 mGy among the large number of people whose initial radiation doses were zero or low would not have substantially affected RERF's risk estimates, which are highly dependent on risks seen at doses >100 mGy.

Thus, residual radiation doses are much lower than initial radiation doses for nearly all A-bomb survivors, and there is substantial error involved in their estimation. Even were information on residual radiation doses to be added, we cannot expect that the precision of risk estimation would improve or the risk estimates would change materially. The numbers of cancer deaths or cancer cases, which are used as the numerators in risk estimation, are values obtained via death certificates and cancer registries independently of radiation dose estimates. Thus, if radiation doses, which serve as the denominator in the equation, are underestimated because of exclusion of residual radiation, cancer risks would be overestimated. If such high risks are used for establishing radiation protection standards, the standards would thus be on the safe side.

Internal exposure

As mentioned at the beginning of this report, residual radiation has been attracting considerable attention, and above all, interest in "internal exposure" has markedly increased recently. The reason why internal exposure has become such a highly publicized issue is thought to be due to the high frequency of thyroid cancer development among children in Chernobyl. In the former Soviet Union era, the fact that the public was not informed of the radioactive contamination was the main reason behind the spread of radiation damage, because people drank milk for a long period without knowledge of the milk's high radioactive concentrations of iodine-131 from cows eating radioactive iodine-contaminated grass. Moreover, there was a lack of nonradioactive iodine preparations for use as a blocking agent to prevent ingested radioactive iodine from being taken up and retained in the thyroid.

Fortunately, since the time of that accident, no example of large levels of internal exposure through a similar pathway has been reported in any part of the world. Nevertheless, some people are still concerned that "internal exposure is 1,000 times more dangerous than external exposure," despite the fact that this concern has no scientific foundation. It is true that the level of external exposure depends only on the level of environmental radiation contamination in the location where the person in question stays and the duration of time spent there, whereas in the case of internal exposure, radiation exposure continues as long as radioactive substances taken into the body are not discharged even when radiation doses decrease in accordance with the physical half-life of such substances. Therefore, it is important to avoid intake of radioactive substances to the extent possible. It is a fact, however, that both internal and external exposures can contribute to such late effects as cancer development.

However, it is important that the level of risks depends on the radiation dose to which cells (probably, tissue stem cells) in which cancer develops are exposed, regardless of whether the exposure is due to external or internal exposure. In the case of external exposure, target organ doses are calculated with consideration to shielding effects by the skin and intervening body tissues. In the case of internal exposure, as can been seen in the relationship between the thyroid and iodine, metabolism in the body differs by radioactive nuclide (element), which may cause uneven distribution in the body. With all these factors taken into account, if the cumulative radiation dose of the target organ is the same, the level of risk should be the same regardless of whether the dose is from internal exposure or external exposure. A comparison of numerous human studies of the cancer effects of internal and external exposures has found that to be the case [Little et al. *Radiation & Environ Biophysics*, 46:299-310, 2007].

In the case of internal exposure, since radiation is emitted radially from radioactive particles taken into the body, the doses near these particles can be very high. However, high radiation dose at a particular site does not necessarily increase cancer risk immediately. Stem cells that are related to carcinogenesis do not exist universally, and therefore if there are no such stem cells in the immediate vicinity of radioactive particles, emitted radiation will not cause cancerous cells. Also, if local radiation dose is extremely high, cells cannot survive, which conversely leads to decreased cancer risk. Based on these findings, the International Commission on Radiological Protection (ICRP) is of the opinion that cancer risk due to radiation from particles taken into the body (i.e. internal exposure) is about the same as risk from external exposure if radioactive substances are distributed evenly throughout the entire body and lower if the substances are distributed unevenly.

For example, a large, high-quality animal experiment showed that comparable doses of radioactive iodine and X-rays caused similar frequencies of thyroid cancer [Lee et al, *Radiation Research*, 92:307-319, 1982]. A comparison of the results of studies of children in the Chernobyl area and children exposed to medical or A-bomb external exposures also have shown similar estimates of risk. In particular, a combined analysis of five major studies of childhood exposure to external radiation showed a relative risk of 8.7 for thyroid cancer after an exposure of 1 Gy [Ron et al, *Radiation Research*, 141:259-77, 1995]. Major studies of the effects of iodine-131 exposure among Chernobyl area children have reported relative risk estimates at 1 Gy of 6.2, 3.2 and 2.9 [Tronko et al. *J Natl Cancer Inst*, 98:897-903, 2006; Zablotska et al. *Brit J Cancer*, 104:181-87, 2011; Brenner et al. *Environmental Health Perspectives*, 119:933-39, 2011]; all of the Chernobyl iodine-131 risk estimates were statistically compatible with, but not higher than, the combined estimate for external radiation exposure.

Finally, with regard to the effects of the accident at the Tokyo Electric Power Company’s Fukushima Daiichi nuclear power plant, some reports have hypothesized exaggerated effects of “internal exposure,” but the best and most comprehensive evidence, some of which is cited above, does not support the argument that internal exposure is more dangerous than external exposure. Because food and drink are now being monitored adequately following the accident and the amount of radioactive substances suspended in the air is extremely small, concerns about internal exposure should not grow any further as long as the current monitoring system is maintained. In terms of effects from radiation exposure immediately after the accident, results of measurements conducted so far by the government of Fukushima Prefecture on tens of thousands of people have shown that the committed dose is less than 1 mSv in more than 99.9% of such people, and the maximum dose observed in this group is as low as the global average background radiation level (2.4 mSv a year).

Addendum: Since uploading “RERF’s Views on Residual Radiation” to our website, it has been pointed out by some that the document seems to have been designed with the aim of explaining that there were no health effects due to residual radiation from the atomic bombings. The material’s actual intent, however, was to explain that in the Hiroshima and Nagasaki atomic bombings, residual radiation levels were low when compared with doses from direct radiation. This “Views” document does not intend to describe an absence of health effects due to residual radiation from the A-bombings.
(May 1, 2013)