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A Survey of Radiation Doses Received by Atomic-Bomb Survivors Residing in the United States

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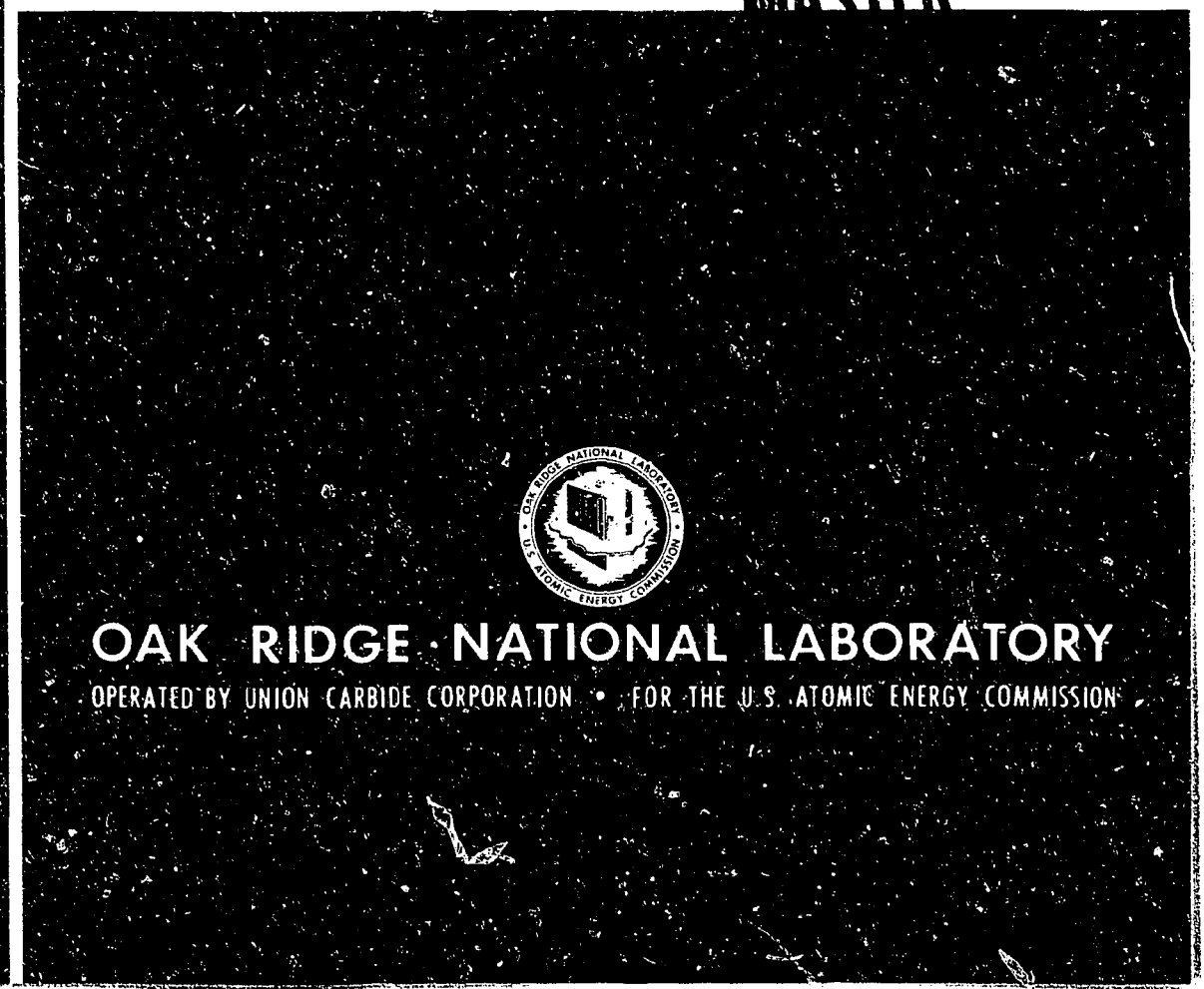

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HEALTH PHYSICS DIVISION

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ABSTRACT

A survey has been completed of 300 of an estimated 500 to 750 survivors of the atomic bombings in Hiroshima and Nagasaki who reside in the United States. Distributions with respect to age, sex, citizenship status, distance from the hypocenter at the time of bombing, and dose from immediate weapon radiation have been tabulated from the results and are presented for this group of 300 survivors. Also presented are survey results concerning exposures to residual radiation from fallout and neutron-induced radioactivity in the areas adjacent to the hypocenter.

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INTRODUCTION

The Health Physics Division of the Oak Ridge National Laboratory (ORNL) has participated for a number of years in liaison studies with the Atomic Bomb Casualty Commission (ABCC), now the Radiation Effects Research Foundation (RERF), in Japan. These liaison studies have been concerned with the development of techniques for estimation of the radiation dose received by survivors of the atomic bombings of Hiroshima and Nagasaki, Japan.[1-5] The techniques developed in these liaison studies have been used by RERF to survey the radiation doses received by over 100,000 survivors residing in Japan.[4,6]

A survey of survivors residing in the United States was undertaken in 1973 by ORNL and RERF at the request and with the cooperation of the United States Atomic Energy Commission (AEC) and continued with the cooperation of the Energy Research and Development Administration (ERDA) which absorbed the research programs of AEC in 1975. Prior to the current program, radiation doses received by several survivors in the United States were estimated jointly by ORNL and ABCC, mostly in response to requests to the AEC by members of the Congress of the United States.

The present survey originated in a growing awareness of the existence of a substantial number of survivors in the United States, principally in the western states. This awareness among survivors in Southern California led to the formation of an organization known as the Committee of Atomic Bomb Survivors of the United States of America, which was chartered as a non-profit organization in 1971 by the State of California. Objectives of the Committee of Atomic Bomb Survivors (as stated in 1974) were:[7]

> "1. To accomplish a nationwide survey for those victims who were exposed to atomic radiation in the Hiroshima and Nagasaki, Japan, bomb blasts.

2. To analyze prepared and compiled data to strengthen the support of the pending Federal Bill No. H. R. 2894,* authored by Congressman Edward Roybal of the Thirteenth Congressional District (Los Angeles), introduced January 24, 1973.

3. To amend, through H. R. 2894, section 102(2) of the Disaster Relief Act of 1970 (42 U. S. C. 4402(2)), to provide reimbursement to certain individuals for medical relief for physical injury suffered by them that is directly attributable to the explosions of the atomic bombs on Hiroshima and Nagasaki, Japan, in August, 1945 and the radioactive fallout from these explosions."

On October 6, 1972, AEC personnel held exploratory talks with Dr. Thomas T. Noguchi, Chief Medical Examiner-Coroner for the County of Los Angeles. Dr. Noguchi has been responsible for coordination of all activities of the local city and county governments on behalf of the survivors who live in Southern California. In December 1972, the House of Delegates of the California Medical Association passed a resolution sponsored by Dr. Noguchi requesting assistance for the survivors. On February 27, 1973, the AEC decided to encourage a scientific program of developing radiation exposure information on the survivors in the Los Angeles area. The ORNL Health Physics Division was asked to cooperate with local volunteers, principally from County agencies and the Southern California Committee of Atomic Bomb Survivors, in the collection of pertinent information on survivors and with ABCC staff in the estimation of radiation doses.

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*The first version of the bill was H. R. 17112 introduced by Congressman Roybal on October 12, 1972, 92nd Congress, 2nd Session. Revisions of this bill were introduced in subsequent sessions of the Congress of the United States. A later version of the bill is H. R. 8152 introduced by Congressman Roybal on June 23, 1975, 94th Congress, 1st Session.

In April 1973, a preliminary study was made by ORNL and ABCC using information on survivors in the Los Angeles area obtained through Dr. Noguchi's office with the aid of local volunteers.[8,9] Tentative estimates were made of the radiation doses received by 44 survivors. Based on this preliminary study, a program was outlined for carrying out a comprehensive survey by (a) collection of preliminary information on survivors by local volunteer groups, (b) search of the files of ABCC for a dose estimate for each survivor, and (c) interview of those without dose estimates by a bilingual staff member of ABCC. To facilitate the collection of preliminary information on survivors, a short questionnaire was prepared at ORNL for immediate use by local volunteers in Los Angeles. In some instances, especially for survivors who immigrated to the United States after 1950, radiation dose estimates had already been made by ABCC.

On January 8, 1974, the AEC authorized extension of the study to other regions of the United States. Exploratory talks were then held with interested officials in the San Francisco area and Hawaii. Those contacted in Hawaii did not believe that a significant number of acknowledged survivors reside in that state. Since neither names nor information on individual survivors were made available, this program did not include survivors who live in Hawaii. Collection of preliminary information from survivors in San Francisco was started in April 1974. Efforts of local volunteers were coordinated by Dr. Francis J. Curry, Director, Department of Public Health for the City and County of San Francisco. To aid and promote the survey, a Northern California Committee of Atomic Bomb Survivors was organized by Mr. Kanji Kuramoto, who participated very actively in the data collection. Chapters of the

Northern California Committee of Atomic Bomb Survivors were organized subsequently in San Francisco, the East Bay area of San Francisco, Sacramento, and San Jose.

By July 1975, information had been accumulated on 300 survivors in the United States.[10] Two hundred and eighty-nine of these survivors were in or near Hiroshima at the time of the bombing on August 6, 1945, and 11 were in or near Nagasaki at the time of the bombing on August 9, 1945. Of the 300 survivors, 137 were registered in the files of RERF, but sufficiently detailed information for dose estimation was available for only 54. The information needed for dose estimation for most of the other 246 survivors was obtained during interviews conducted by RERF and ORNL on the West Coast in November and December, 1974, and in March and April, 1975. In these interviews, old maps and aerial photographs of the two cities were used to establish the location of each survivor at the time of bombing. Other relevant information was also obtained during the interviews. In 14 cases in which the survivor could not provide sufficient information for dose estimation, interviews were conducted by the RERF with relatives living in either Hiroshima or Nagasaki. One of these cases is still under study.

GENERAL INFORMATION ON SURVIVORS IN THE UNITED STATES

Over 200 survivors are believed to reside in Southern California, 150 in Northern California, and 150 in Hawaii. The total number of survivors in the United States is estimated to be 500 to 750.[7] Geographic locations of the 300 survivors participating in this survey are shown in Table 1. Of these 300 survivors, only one, a prisoner of

Table 1. Geographic Location Of Survivors In The U.S. Included In Survey.

STATE OR AREA	NUMBER
Arkansas	1
California	
Eureka	3
Fresno	7
Los Angeles	148
Sacramento	25
San Jose	23
San Francisco	76
Colorado	4
Florida	1
Illinois	1
Michigan	1
Oregon	2
Pennsylvania	1
Texas	1
Utah	5
Washington	1
TOTAL	300

war at the time of bombing, was not of Japanese ancestry. It is known, however, that other American prisoners of war were located in the Nagasaki area at the time of bombing.[11-13]

The citizenship status and sex of the 300 survivors in the survey are summarized in Table 2. Among survivors identified as either naturalized citizens or permanent resident aliens, the ratio of females to males was about four-to-one. The large number of females in these groups is due to the marriage of Japanese female survivors to U.S. citizens. More than two-thirds of all survivors in the survey were female as shown in Table 2.

Several factors contributed to the presence of natural-born citizens of the United States in Japan during the war.[14-16] Many of the American-born Japanese (*Nisei*) were attending school in Japan when war broke out and were obliged to remain there until after the war. Other *Nisei* had returned to Japan with their Japanese immigrant (*Issei*) parents immediately before the war due to anticipated "precautionary" measures that eventually resulted in the placement of West Coast Japanese-Americans in relocation centers in the interior of the United States.

The survivors' ages at the time of bombing are shown in Figure 1. It can be seen from this figure that almost two-thirds of the survivors in this survey were between the ages of 10 and 25 years at that time. This age distribution resulted mainly from the presence of a large number of *Nisei* students in Hiroshima.

Table 2. Summary of Information on Citizenship and Sex of Survivors in the United States.

CITIZENSHIP STATUS	NUMBER OF MALES	NUMBER OF FEMALES	TOTAL NUMBER
Natural Born U.S. Citizen	50	81	131
Naturalized U.S. Citizen	11	37	48
Permanent Resident Alien	18	92	110
No Information	6	5	11
TOTALS	85	215	300

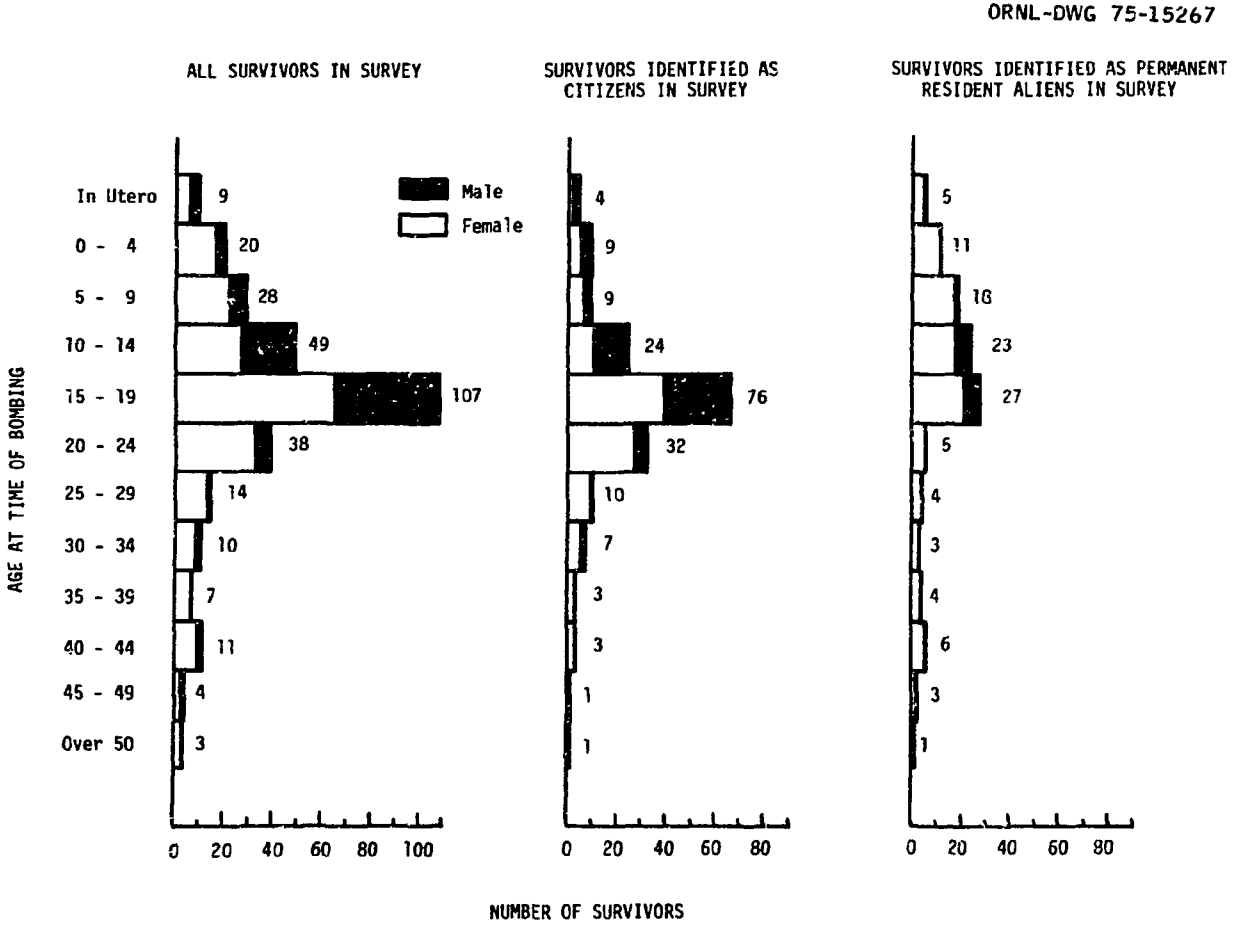

Figure 1. Summary Of The Ages At Times of Bombing For Survivors In The United States.

RADIATION DOSE ESTIMATES FOR SURVIVORS IN SURVEY

Distance from the hypocenter and shielding determine the dose received by a survivor from immediate weapon radiation.[1-5] In interviews with survivors, the site of each individual at the time of bombing has been carefully documented. This information, together with the best available estimates of the location of the hypocenter or ground zero in each city,[17-20] was used to determine the distance of the survivors from the respective hypocenters. These estimates of distance are summarized in Figure 2 for all survivors participating in the survey. Survivors within a distance of 2,500m (about 1.5 miles) are usually referred to as the proximal group, those between 2,500 and 10,000m (about 1.5 to 6.2 miles) as the distal group, and those at distances of over 10,000m (about 6.2 miles) as the "not-in-city" group at the time of bombing.[21,22]

The decrease in immediate weapon radiation with distance from the hypocenter is given by the air-dose curves developed by ORNL[23] and later verified by the National Institute of Radiological Sciences (NIRS)[24] in Japan. These curves are different for the two cities due to the designs and yields of the weapons.[23] The yields of the Hiroshima and Nagasaki weapons have now been estimated to have released an energy equivalent to 12.5 and 22 kilotons of TNT, respectively.[23,25] Even without regard for shielding, the radiation doses received by individuals in the distal group were less than 1 rad in Hiroshima and less than 3 rads in Nagasaki. Due to their large distances from the hypocenters, individuals in the not-in-city group were not exposed to immediate weapon radiation.

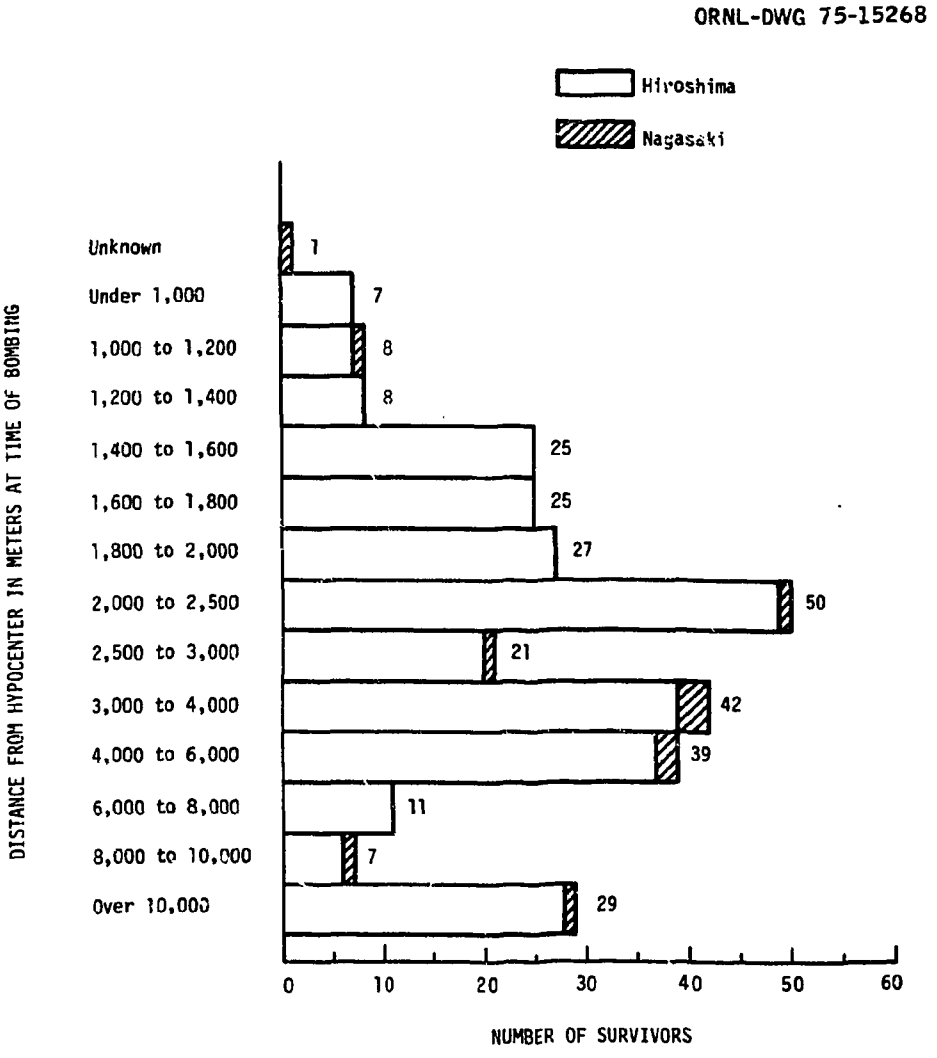

Figure 2. Summary Of Distances From The Hypocenters At Time Of Bombing For Survivors In The United States.

In interviews, especially of survivors in the proximal group, location with respect to structures or nearby objects that may have shielded an individual against weapon radiation was also documented carefully. The shielding of an individual inside a Japanese residence or other light structure was calculated by the "9 parameter formula" developed by ORNL.[5,26] For individuals inside a concrete or other heavy structure or in the open but partially shielded by structures or other objects, the shielding of each was determined by the "globe technique" also developed at ORNL.[1,3,8] These individually determined shielding and distance factors were used with the air-dose curves to obtain the radiation doses summarized in Table 3. In Hiroshima, both neutrons and gamma rays contributed importantly to the radiation exposure, while the radiation exposure of survivors in Nagasaki was almost exclusively from gamma rays. These differing radiation characteristics were due to differences in the design of the two weapons.[23,27] Estimates of dose from immediate weapon radiation for survivors in the proximal group of this survey ranged from less than 1 rad to 490 rads in Nagasaki and 510 rads in Hiroshima.

Other radiation exposures of interest in the interviews with survivors were those from early entry into areas adjacent to the hypocenters and from immediate or local fallout of fission products. The number of indiviudals in the survey receiving exposures from both fallout and early entry, from fallout only, and from early entry only are summarized in Table 4 as a function of their locations, i. e., proximal group, distal group, or not-in-city group, at the time of bombing.

Table 3. Summary Of Radiation Doses Received By Survivors At The Time Of Bombing.

RANGE OF RADIATION ABSORBED DOSE IN RADS	NUMBER IN PROXIMAL GROUP*	NUMBER IN DISTAL GROUP**	NUMBER IN NOT-IN-CITY GROUP***
Not Exposed	---	---	29
Less than 1	26	120	
1 to 5	49		
5 to 10	24		
10 to 20	18		
20 to 50	16		
50 to 100	5		
100 to 200	3		
200 or more	9		
No Estimate	1		
TOTALS	151	120	29

* Less than 2,500m from hypocenter
** Between 2,500 and 10,000m from hypocenter
*** Over 10,000m from hypocenter

Table 4. Summary Of Fallout And Early Entry Exposures Subsequent To Time Of Bombing In Terms Of Location At Time Of Bombing.

LOCATION AT TIME OF BOMBING	NUMBER OF SURVIVORS RECEIVING BOTH FALLOUT AND EARLY ENTRY	NUMBER OF SURVIVORS RECEIVING ONLY FALLOUT EXPOSURES	NUMBER OF SURVIVORS RECEIVING ONLY EARLY ENTRY EXPOSURES
Proximal Group*	33	60	20
Distal Group**	24	18	45
Not-In-City Group***	3	1	17
TOTAL	60	79	82

* Less than 2,500m from hypocenter
** Between 2,500 and 10,000m from hypocenter
*** Over 10,000m from hypocenter

Radiation doses to survivors resulting from local fallout of fission products can be estimated from measurements of residual radioactivity made in Hiroshima and Nagasaki within several weeks to several months after the explosions, but these measurements cannot be used to estimate radiation doses to survivors resulting from early entry into areas adjacent to the hypocenters.[2] The radioactivity induced in the soil at the hypocenter by neutrons released during the explosions was due mainly to radioactive nuclides with very short half-lives. Detailed calculations[28-30] indicate that the neutron-induced radioactivity was significant only within a period of about 3 days and only within a distance of about 500m (0.3 mile) from the hypocenters. Due to raging fires, survivors migrated away from the hypocenter areas on the day of the bombing,[28] but some did return to search in these areas on the second and third days (see Table 4). Estimates of the gamma-ray dose resulting from early entry into the areas adjacent to the hypocenters in either Hiroshima or Nagasaki are 5 rads or less. These estimates are based on knowledge of the times and areas of early entry obtained in interviews with the survivors.

Local fallout from the weapons in Hiroshima and Nagasaki occurred as "black rains" in directions downwind of the hypocenters.[31,32] Depending on distance from the hypocenters, the rains started 15 minutes to 1 hour after the explosions and lasted 30 minutes to 2 hours. These black or dark colored rains contained radioactive fission products and other debris from the weapons mixed with dust and dirt that were drawn upward immediately after the explosion and with soot and dust that rose from fires adjacent to the hypocenters. Based on residual radiation

measurements in areas of heaviest black rainfall in the two cities, the radiation doses received by survivors from gamma-ray exposures from local fallout have been estimated to range up to about 10 rads in Hiroshima and 50 rads in Nagasaki.[28,32-34] The most significant area of fallout was the Nishiyama region of Nagasaki located about 3,000m east of the hypocenter.

DISCUSSION

The magnitude of radiation exposure due to fallout at Hiroshima and Nagasaki was much below that experienced by inhabitants of certain atolls in the Marshall Islands and by Japanese fishermen after the test of a thermonuclear device on Bikini on March 1, 1954.[35] The greater distance of these individuals from the test device, than the survivors of Hiroshima and Nagasaki from the weapon detonations, was more than compensated by the nature of the test and magnitude of the release of energy and radioactivity in the Pacific. Since the Pacific test was conducted at a level relatively near the ground, a greater quantity of neutron-activated soil was drawn into the atmosphere and ultimately deposited as fallout. Furthermore, the Pacific test had an estimated yield of energy equivalent to 17 megatons (17,000 kilotons) of TNT[35] which was about 770 times the estimated energy yield of the Nagasaki weapon and 1,360 times that of the Hiroshima weapon.

For survivors of Hiroshima and Nagasaki, the dose estimates from both fallout and early entry can be made only in terms of ranges below upper limits due to uncertainties in the available data. In both cases, the necessary data to map out the exposure rates at all sites in the

affected areas are not available.[33] Furthermore, the movements of individuals in terms of both location and time cannot be defined sufficiently to permit precision in estimation even if site-specific exposure rates had been available.[28,30] Both site-specific exposures and locations of survivors were much more reliable for the immediate weapons radiation than for the fallout and early entry exposures.

Health risks associated with the radiation exposure incurred by survivors will not be discussed here but have been treated extensively in recent reports by the Committee on the Biological Effects of Ionizing Radiation (BEIR) of the National Academy of Sciences[36] and the United Nations Scientific Committee on the Effects of Atomic Radiation (UNSCEAR).[37] Additional source material for the consideration of health effects in survivors is available in various technical reports of the Atomic Bomb Casualty Commission. Source material in many of these reports has recently been presented in summary form[38,39] in a supplement of the *Journal of Radiation Research* entitled, "A Review of Thirty Years Study of Hiroshima and Nagasaki Atomic Bomb Survivors," and in several other reports.[27,40]

Possible biases may exist in this sample of 300 relative to the underlying total population of survivors in the United States because this project was conceived as one of voluntary participation rather than total ascertainment. Although considerable publicity was developed through news coverage in local Japanese and English newspapers and in TV and radio broadcasts, systematic search and persuasion was not employed out of regard for the individual sensitivities of the survivors. Some individuals may have been reluctant to identify themselves as

survivors; others may have failed to come forward because their greater distance from the hypocenter would occasion a low level of concern. Due to bias introduced by these factors, the 300 survivors cannot be regarded as a random sample of the entire population in the United States.

SUMMARY

A survey has been completed of 300 of an estimated 500 to 750 survivors of the atomic bombings of Hiroshima and Nagasaki who reside in the United States. Analyses of age and sex distributions were presented for this group of 300 survivors and on subgroups according to citizenship status. Also presented were distributions of distance from the hypocenter at the time of bombing and dose estimates from immediate weapon radiation. In broad dose ranges, 175 survivors received less than 1 rad, 91 received 1 to 20 rads, 24 received 20 to 200 rads, and 9 received 200 rads or more from exposure to immediate weapon radiation. Of the 300 survivors in the survey, 139 reported being in areas of the black fallout rains and 142 reported entering the areas adjacent to the hypocenter within 3 days after the bombings. Doses received by survivors from gamma-ray exposures to fallout in Hiroshima have been estimated to be 10 rads or less, and those received from gamma-ray exposures to fallout in Nagasaki to be 50 rads or less. The most significant area of fallout was the Nishiyama region of Nagasaki. Estimates of the gamma-ray dose resulting from early entry into areas adjacent to the hypocenters in either city were 5 rads or less for the survivors in this survey.

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CITY AND COUNTY OF SAN FRANCISCO, SAN FRANCISCO, CALIFORNIA

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