

Fact Sheet



Defense Threat Reduction Agency

Radiation Exposure in U.S. Atmospheric Nuclear Weapons Testing

The Defense Threat Reduction Agency (DTRA) is the Department of Defense (DOD) executive agent for the Nuclear Test Personnel Review (NTPR) Program, which serves the approximately 550,000 veterans who participated in U.S. atmospheric nuclear tests, served with the U.S. occupation forces of Hiroshima and Nagasaki, Japan, or were prisoners of war in Japan at the conclusion of World War II. The primary purpose of the NTPR Program is to provide participation data and radiation dose information for veterans.

U.S. Atmospheric Nuclear Tests

Military and civilian personnel participated in U.S. atmospheric nuclear tests that were conducted primarily in Nevada and the Pacific Ocean between 1945 and 1962. Many participants were exposed to low levels of ionizing radiation while performing various activities. Over 99 percent of these participants received radiation doses that were below the current federal occupational whole body dose limit (5 rem per year); the average whole body dose was less than 0.6 rem (see "rem" definition below). Current occupational dose limits for DOD personnel are codified in DOD instruction 6055.8 and are based upon the Environmental Protection Agency's "Radiation Protection Guidance to Federal Agencies for Occupational Exposure" (1987).

Hiroshima and Nagasaki Occupation Forces

Veterans participated in the post-World War II occupation of Hiroshima and Nagasaki, Japan, or were prisoners of war in these areas; over 95 percent of them received radiation doses below 0.1 rem. Only those Nagasaki occupation forces that regularly entered the Nishiyama area had the potential to receive doses up to and exceeding 1 rem.

Exposure and Dose Units

Ionizing radiation is capable of displacing electrons from atoms or molecules, thereby producing ions. By comparison, other radiations (such as microwaves and lasers) are not capable of producing ions and are examples of nonionizing radiation. Therefore, quantifying radiation exposure is a vital aspect of radiation protection.

Ionizing radiation survey instruments used during the atmospheric testing era (as well as many in use today) commonly read in roentgens (R), the traditional unit of *exposure*. This unit is defined only for photons (gamma and x-rays) in air, making it of limited use when other radiation types (such as beta particles) or mediums (such as tissue) are concerned.

The "rad" is the traditional unit of *absorbed dose*, which is defined as energy absorbed per unit mass (usually in tissue). While absorbed dose is not limited to photons in air, it does not account for the effectiveness of different types of ionizing radiation to produce biological damage (i.e., alpha, beta, gamma, and neutron). For example, neutrons of specific energies can be more damaging than gamma radiation.

The “rem” is the traditional unit of *dose equivalent*, which is used to quantify the potential biological effect of a given absorbed dose in humans. Under most circumstances, it can be assumed that 1 R = 1 rad = 1 rem. Since most occupationally-exposed individuals receive doses that are much less than 1 rem, it is often convenient to speak in terms of millirem, or 1/1000 of a rem.

Radiation Risk

According to the National Council on Radiation Protection and Measurements (NCRP, Report No. 160, Table 1.1), the general U.S. population receives about 0.62 rem per year from natural background radiation sources (radon, cosmic rays, and rocks) and man-made radiation sources (medical diagnostic x-rays and consumer products). As a basis of comparison, a standard diagnostic chest x-ray delivers a radiation dose of roughly 0.02 rem.

The Health Physics Society states that the risk of health effects are either too small to be observed or are nonexistent at doses below 5 rem per year, and that radiation-induced health effects have not been consistently demonstrated below 10 rem.¹ This position is substantiated by the Radiation Effects Research Foundation (formerly the Atomic Bomb Casualty Commission), which has studied the health effects of radiation exposure in survivors of the atomic bombings at Hiroshima and Nagasaki since 1946.²

The American Cancer Society (ACS) and the National Cancer Institute (NCI) report the lifetime risk of developing any type of cancer for members of the U.S. general population to be greater than 40 percent. The lifetime risk is almost 45 percent for males (only), prompting ACS to estimate a man’s lifetime risk of developing cancer to be slightly less than 1 in 2. The risk of being diagnosed with cancer generally increases with age, as evidenced by the fact that three out of every four cancers are diagnosed in persons 55 and older. For more information on cancer incidence and diagnosis, contact ACS (800-ACS-2345, www.cancer.org) or NCI (800-4-CANCER, www.cancer.gov).

The federal occupational whole body dose limit (5 rem per year) is believed to carry a low risk of causing additional cancers above the level normally observed in the general population. This is supported by the lifetime risk model recently developed by the National Academy of Sciences Committee to Assess Health Risks from Exposure to Low Levels of Ionizing Radiation (BEIR VII Report), which indicates that one in 100 persons would be expected to develop some form of cancer (fatal or non-fatal) from a radiation dose of 10 rem above natural background radiation. By comparison, 42 of the 100 persons would be expected to develop cancer from other causes. At a dose of 5 rem, less than three excess fatal cancers would be expected in an exposed population of 1,000.

Film Badges

The most common method for measuring dose from ionizing radiation at U.S. atmospheric nuclear tests was the issuance of a film badge. Of the 237,000 DOD participants, about 45 percent have recorded doses from film badges. None of the Hiroshima or Nagasaki occupation forces were issued film badges. The majority of films from these badges are maintained by the Department of Energy at the Nuclear Testing Archive in Las Vegas, Nevada (702-295-1628).

Until 1955, the availability of film badges varied. There were situations in which a group of personnel, such as a platoon or ship/aircraft crew, experienced similar conditions and were assigned a single film badge to represent the radiation dose for every individual in the group (cohort). The practice of monitoring a group in this manner was chosen because every member of the group performed similar work in roughly the same radiological environment over a similar duration of time.

After 1955, the DOD and the Atomic Energy Commission changed their policies to require that all participants having the potential for radiation exposure at an atmospheric nuclear test site be issued a film badge. Some film badges were damaged (by heat, humidity, and other causes), rendering them unreadable. A small number

of film badges were issued and not returned or were lost before they could be analyzed.

For additional information on film badges, see the National Research Council (NRC) report "Film Badge Dosimetry in Atmospheric Nuclear Tests."³

Reconstructed Doses

When radiation doses from film badges are not available, the NTPR Program performs dose reconstructions to calculate a dose using information contained in other records. These records include instrument readings from radiological surveys, radiochemistry data from aircraft sampling of nuclear clouds, and laboratory results of analyses. As a result, a significant portion of the NTPR effort has focused on characterization of radiological environments and developing technical assessment procedures to assess doses for personnel who were not issued film badges or personnel whose records are missing or incomplete. Veterans wishing to assist the NTPR Program's dose reconstruction process may provide copies of military records to the NTPR Program.

Dose Reconstruction Methodology

In 1985, the NTPR dose reconstruction methodology was published in Title 32, Code of Federal Regulations, Part 218 (32 CFR 218). This methodology has been developed to provide a comprehensive analysis of both external and internal radiation doses, for application to units as well as individuals. Since 1985, the scientific methods used by the NTPR Program have been reviewed several times by the Government Accountability Office and the NRC, most recently in 2003. For more information, see the NTPR Program: Program Reviews and Scientific Studies fact sheet on DTRA's webpage.

The NTPR Program uses the following three alternative approaches, as described in 32 CFR 218, to determine the radiation dose to individuals for whom film badge data are not available:

1. *Determination of dose potential.* Activities of an individual (or their unit) for the period of participation are researched. Unit locations and movements of the veteran are related to areas of radioactivity and radiation exposure. If personnel were beyond the range of initial radiation exposure from nuclear detonations (several miles), were not exposed to fallout, did not enter a radiologically contaminated area, and did not come into contact with radioactive materials, the dose evaluation will conclude that no radiation dose was received.
2. *Dose based on film badges of others.* Film badge data from badged personnel are used to derive individual radiation doses for unbadged personnel. A homogeneous group of participants is identified, consisting of personnel who performed common activities and therefore had a similar potential for radiation exposure. Identification of homogeneous groups is based upon research of historical records, technical reports, and correspondence. Using standard statistical methods, the film badge data are examined along with unit records and any available statements/questionnaires concerning the veteran's activities to determine whether it is valid to assign an entire group's average radiation dose to an individual. Often the dose or the periods over which film badges were worn indicate that the group should be further subdivided into personnel performing common functions before proceeding with the analysis. For each homogeneous group, the mean and upper-bound radiation doses are obtained from the distribution of film badge readings. The upper-bound dose is the value corresponding to a 95 percent probability that the actual dose received by the veteran is lower. This procedure ensures that unbadged personnel are provided mean and upper-bound radiation doses that reflect the uncertainties exhibited by the spread of film badge readings within their group. If individuals cannot be associated with a specific homogeneous group, then film badge doses for this group are not used.
3. *Dose calculation.* In accordance with 32 CFR 218, rigorous dose calculations are performed when film badge data is unavailable for all or part of the exposure period. The NTPR Program also performs calculations if film badges were damaged and cannot yield reliable dose information, if unique activities are credited to specific individuals, or if a neutron dose or a dose to the skin or an internal organ is necessary.

These calculations involve correlating the activities of an individual (as described in statements, questionnaires, and historical records) with the radiological environments encountered.

Dose Calculation Process

The calculation of a radiation dose is a scientific practice commonly employed by health physicists when an individual's radiation exposure cannot be quantified by dosimetry (such as a film badge). The general process of radiation dose reconstruction for veterans is described here:

- The conditions of radiation exposure are reconstructed to include all known activities based on statements/questionnaires from the veteran, as well as information from official reports and historical documents. These statements and questionnaires form the basis for documenting the veteran's activities and are used along with radiological information to provide dose information.
- The radiation environment is characterized in time and space, and matched with the activities and locations of the unit or individual. In addition to external gamma radiation measured by film badges, the contributions from other types of radiation (such as neutrons) are considered and included.
- Individual activities, as documented by statements and questionnaires from the veteran (including available shielding, body position, and other factors) are quantitatively associated with radiological environment information and a total integrated dose is calculated.
- Any available and valid (undamaged and otherwise scientifically accurate) film badge dosimetry is analyzed and compared with the calculated radiation dose to establish correlation confidence to the calculations.
- An uncertainty analysis is performed to consider the relative sensitivities of all parameter inputs and to provide an upper-bound radiation dose estimate (95th percentile).

Internal Doses

Where the potential existed for inhalation or ingestion of radioactive materials or fallout, internal dose commitments from alpha, beta, and gamma radiation to relevant target organs are derived. Since radioactive materials entering the body deliver their dose over a period of time (rather than instantly), internal radiation doses are determined for a 50-year period after the initial exposure, even if this period extends beyond the actual or expected lifetime of the veteran.

Comparison of Reconstructed Doses to Film Badge Records

Prior to implementation of the NTPR dose reconstruction methodology, it was applied to specific scenarios in which film badge data were available to determine if the methodology could accurately predict the actual film badge results. All parameters relating to radiation exposure (such as body position and activities performed) were identified, allowing the reconstructed dose to be directly compared to actual film badge readings. The resulting correlations were in satisfactory agreement and provided a high degree of confidence that NTPR dose reconstruction methodologies, as codified in 32 CFR 218, accurately predict film badge results.

Expedited Processing

In 2006 and 2007, the Veterans' Advisory Board on Dose Reconstruction (VBDR) recommended that the NTPR Program develop screening procedures for skin, prostate, and posterior subcapsular cataract dose assessments that would allow expedited processing of cases for which the doses are well below or well above the level likely to result in a successful claim (thereby reducing the time required to generate an analysis of these doses). The VBDR also recommended that worst-case upper bound doses be used to provide maximum benefit of the doubt for the veteran. Based on subsequent recommendations by VBDR, expedited processing was expanded to include all but a select few organs.

Utilizing the scientific methods described above, bounding assumptions about exposure scenarios, and previously calculated doses, the NTPR Program established conservative theoretical maximum doses that are much higher than most dose assessments and upper-bound dose determinations that were performed previously. Expedited doses are based on worst-case parameters and assumptions, not all of which may have been encountered by participating veterans; nevertheless, they are intended to adequately encompass any activities performed. To provide maximum benefit of the doubt for the veterans and ensure that reported doses are not less than actual doses, veteran input is carefully reviewed to ensure that no activities in an actual exposure scenario would result in a higher dose than that generated via the expedited process.

Dose Information Requests

The NTPR Program can provide or research information relevant to a veteran's radiation exposure environment, records, or estimates when requested by Veterans Affairs.

Please note: radiation dose information or confirmation of participation from the NTPR Program is not a prerequisite to filing a compensation claim or obtaining priority health care.

NTPR Inquiries

Individuals seeking information about the NTPR Program can address their inquiries to:

Defense Threat Reduction Agency
ATTN: RD-NTS (NTPR)
8725 John J. Kingman Road, Stop 6201
Fort Belvoir, Virginia 22060-6201
NTPR Program Helpline : 800-462-3683
E-mail: dtra-ntpr@mail.mil
<http://www.dtra.mil/DTRA-Mission/Reference-Documents/NTPR-info/>

September 2021

¹ Health Physics Society, *Radiation Risk in Perspective* (2004). <http://hps.org/documents/radiationrisk.pdf>

² Radiation Effects Research Foundation, *Life Span Study Report 13: Solid cancer and noncancer disease mortality: 1950-1997* (2003).

³ National Research Council, *Film Badge Dosimetry in Atmospheric Nuclear Tests* (1989).
http://books.nap.edu/catalog.php?record_id=1404