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Occupational Dose from Elevated Ambient Levels of External Radiation

Daniel J. Strom, John J. Fix, Steven E. Merwin, and Bruce A. Napier

Introduction

It is possible that external dosimetry results account for both occupational and environmental penetrating radiation exposures if control dosimeters were not exposed to elevated ambient levels of external radiation (EALER) due to weapons production operations. EALER may come from 1) passing plumes of radioactive gas (the neutron activation product ^{41}Ar predominates), 2) sky shine, and 3) ground contamination.

As discussed below, under many circumstances doses due to EALER may have been recorded by personnel dosimeters, and would not need to be added separately in the dose reconstruction.

Control Dosimeters

External dosimeters using film or thermoluminescent dosimeters have been used for occupational radiation monitoring since the 1940s. To account for background radiation levels, which are not traditionally included in occupational radiation dose records, control dosimeters have been used from the outset. Good radiation protection practice dictates that, during shipment, a control dosimeter accompany each batch of dosimeters issued to workers. Between manufacture (or annealing) and issuance, and between retrieval and processing, each shipment of dosimeters is irradiated by natural cosmic and terrestrial radiation sources, and potentially inadvertently irradiated by other sources. The function of the control dosimeter is to measure all non-occupational radiation exposure to the batch of dosimeters. On processing, the reading from the control dosimeter is subtracted from the reading of each of the other dosimeters in the batch, yielding a result for each dosimeter that is uniquely due to occupational radiation exposure. Note that the subtraction could occur with raw data, such as optical density readings for film or glow curves, or with transformed data, such as exposures in R, absorbed doses in rads or grays, or dose equivalents in rems or sieverts.

Were Control Dosimeters Exposed to Elevated Ambient Levels of External Radiation?

The question arises of where the control dosimeters were stored. From the intended use of control dosimeters, it is clear that controls should be subjected to exactly the same *non-occupational* radiation exposure as the issued dosimeters, and differ only in the *occupational* component. The implementation of this intention, that is, procedures for issuance and retrieval of dosimeters, likely differed over time within a given facility and certainly differed among various DOE and AWE sites. For example, at large facilities like Hanford, the Idaho National Engineering and Environmental Laboratory, Los Alamos National Laboratory, and Savannah River, controls may have been kept at a central dosimeter location, or distributed with batches of dosimeters to remote identification (ID) badge/dosimeter exchange buildings such as guard stations near reactors, reprocessing facilities, or manufacturing facilities. During some periods of time, dosimeters were incorporated into ID badges to ensure that no one entered without a dosimeter, and these ID badges were picked up at the entrance station at the beginning of each shift, and turned in there at the end of each shift.

If control dosimeters were kept at remote exchange facilities, then they would have recorded elevated ambient levels of external radiation (EALER) at those facilities. Such doses from EALER recorded by the controls would subsequently have been subtracted from each worker’s dosimeter reading. However, if control dosimeters were kept at a distant, central badging facility where ambient radiation levels were lower than in the work areas, then each worker’s dosimeter would have recorded not only his or her occupational exposure, but his or her exposure to elevated ambient radiation levels. In the latter case, no adjustment for occupational environmental radiation levels is needed, since they would have been included in the worker's occupational measurements.

Elevated Ambient Levels of External Radiation (EALER)

Near operating reactor facilities in the early days, one important component of external environmental dose arose from submersion in, or irradiation at a distance from, a plume containing ^{41}Ar (with a radiological half-life of 1.83 hours), formed when naturally-occurring ^{40}Ar nuclei absorb neutrons. The emissions from ^{41}Ar are primarily a 1.2-MeV (maximum) β particle and a 1.3-MeV γ photon. A wooden badge exchange building would likely provide very little shielding or attenuation of the γ emission, and if air exchange rates at the control dosimeter storage point were high, even the β component may have approached outdoor levels.

Besides radiation from airborne releases of radioactive materials, other components of EALER could arise from 1) scattered radiation from waste trenches, storage facilities, etc., 2) terrestrial contamination, and 3) sky shine (radiation scattered to the ground from air over nuclear or high-energy accelerator facilities). However, these components are unlikely to have been the same at dosimeter exchange facilities as on the rest of the site, so that control dosimeters stored at remote exchange facilities would not have recorded this component.

Issues

1. What sites had potential for significant ambient environmental external radiation exposure (EALER)?

Sites with potential for significant EALER include those with

- operating production reactors,
- fuel reprocessing,
- other radiochemical processing facilities,
- atmospheric nuclear weapons testing,
- underground nuclear weapons testing with significant venting of fission gasses,
- accidental airborne releases of radioactive materials, and
- certain high-energy accelerators (in the early years).

Sites meeting these criteria include Hanford (which included Hanford Laboratories, what became Pacific Northwest National Laboratory in 1965), Savannah River, Oak Ridge National Laboratory, Idaho National Engineering and Environmental Laboratory, the Nevada Test Site, and Los Alamos National Laboratory.

2. How elevated could the doses be?

As an example, doses from EALER at Hanford could have been as high as a few millirem per day in some cases during the 1940s. Till et al. (2002) reported measurements near the Redox Plant at Hanford as high as 36 mrad/day, averaging 8.5 mrad/day between April 1952 and November 1954, with some outdoor contamination areas reaching 6 mrem/hour (p. 4-6). While control dosimeters were not kept in such high dose-rate areas, there is some possibility of elevated readings where control dosimeters were stored.

3. What sites had potential for significant EALER that might not have been measured by a claimant's dosimeter? That is, at what sites were control dosimeters exposed to EALER?

Large sites might have had inhomogeneous EALER and a need for distributing control dosimeters with batches intended for particular areas. For example, film badges and TLDs were processed at Hanford in the 3701 gatehouse from the beginning of the film badge program in October 1944. In the early days, a worker who had clearance for several areas would have a badge in each one of those areas, as many as 7 badges issued simultaneously. A worker's badge would be stored at the area badge house. Routine practice at Hanford involved dosimeter exchange buildings at each major operating area. Workers obtained their individually assigned dosimeters upon ingress and left the dosimeter upon egress. Along with the dosimeters in each one of those locations (known as "badge houses") there would also be control dosimeters placed in the badge house. At some point (history unknown as of this revision), Hanford switched to a single dosimeter being issued at a time to an individual.

4. For what years was this possible?

In general, there will be a point in time, probably no later than 1970, after which there will be no need to assess a specific EALER to add to claimants' dose histories, because 1) levels were so low they would not significantly impact probability of causation, and 2) control dosimeters were kept out of harm's way and EALER would not have been subtracted. As environmental monitoring programs matured, environmental TLD measurements rule out significant EALER values.

For any given site, however, the cutoff date may be earlier than 1970. This can only be established for a particular site by reviewing site activities, as has been done for Hanford, Savannah River, Oak Ridge National Laboratory, and a few other sites. In the processing of developing site-specific Technical Basis Documents for this project, an evaluation of practices involving control badge placement is being conducted for each site. Although specific timelines will be reported in the site-specific TBDs once developed, it is clear that by 1980 all sites had adopted procedures that ensured that control badges were not stored in elevated background environments.

Conclusions

External dosimetry results account for both occupational and environmental penetrating radiation exposures if control dosimeters were not exposed to elevated environmental radiation due to weapons production operations. Elevated ambient levels of external radiation exposure (EALER) may come from 1) passing plumes of radioactive gas (neutron activation product ^{41}Ar predominates), 2) sky shine, and 3) ground contamination. Not all DOE and AWE sites may have experienced the problem of missed EALER.

Although there are uncertainties about the periods of time during which this may have happened, the sites at which it may have happened, and the subgroups of workers for whom it may be significant, after 1970 missed EALER will not be significant in most cases. After 1980, missed EALER was essentially nonexistent at DOE facilities.

It is concluded that for the years 1980 and later, environmental (on-site ambient) doses need not be considered when evaluating occupational doses because they would have been accounted for by personnel dosimeters. For extremely small environmental doses that were received but not reported due to dosimeter detection limits or reporting practices (i.e., in cases in which the reported dose is zero for a particular badge cycle), the assignment of missed doses according to procedures developed for this project ensures that such environmental doses have been accounted for. A subsequent revision to this document will provide specific dates for each site establishing when it is known that control badges were stored in appropriate locations, which will allow for environmental doses to not be evaluated for certain sites prior to 1980.

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