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PUBLICATION RECORD

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01/09/2004	01	Approved issue of Revision 01. Revised to add page headers, correct editorials, acronyms and to change references to TBD to Site Profile where applicable. Initiated by Edward D. Scalsky.
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05/23/2007	03	Approved Revision 03 initiated to add Attributions and Annotations section. Constitutes a total rewrite of the document. No further changes occurred as a result of formal internal review. This revision results in no change to the assigned dose and no PER is required. Training required: As determined by the Task Manager. Initiated by Edward D. Scalsky.

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ACRONYMS AND ABBREVIATIONS

DOE	U. S. Department of Energy
EEOICPA	Energy Employees Occupational Illness Compensation Program Act of 2000
IMBA	Integrated Modules for Bioassay Analysis
IREP	Interactive RadioEpidemiological Program
MDA	minimum detectable activity
mi	mile
NIOSH	National Institute for Occupational Safety and Health
ORAU	Oak Ridge Associated Universities
POC	probability of causation
PUREX	plutonium-uranium extraction
RATCHET	Regional Atmospheric Transport Code for Hanford Emission Tracking
REDOX	reduction oxidation
TBD	technical basis document
U.S.C.	United States Code
§	section or sections

1.1 INTRODUCTION

Technical basis documents and site profile documents are not official determinations made by the National Institute for Occupational Safety and Health (NIOSH) but are rather general working documents that provide historic background information and guidance to assist in the preparation of dose reconstructions for particular sites or categories of sites. They will be revised in the event additional relevant information is obtained about the affected site(s). These documents may be used to assist NIOSH staff in the completion of the individual work required for each dose reconstruction.

In this document the word "facility" is used as a general term for an area, building, or group of buildings that served a specific purpose at a site. It does not necessarily connote an "atomic weapons employer facility" or a "Department of Energy [DOE] facility" as defined in the Energy Employees Occupational Illness Compensation Program Act [EEOICPA; 42 U.S.C. § 7384l(5) and (12)]. EEOICPA defines a DOE facility as "any building, structure, or premise, including the grounds upon which such building, structure, or premise is located … in which operations are, or have been, conducted by, or on behalf of, the Department of Energy (except for buildings, structures, premises, grounds, or operations … pertaining to the Naval Nuclear Propulsion Program)" [42 U.S.C. § 7384l(12)]. Accordingly, except for the exclusion for the Naval Nuclear Propulsion Program noted above, any facility that performs or performed DOE operations of any nature whatsoever is a DOE facility encompassed by EEOICPA.

For employees of DOE or its contractors with cancer, the DOE facility definition only determines eligibility for a dose reconstruction, which is a prerequisite to a compensation decision (except for members of the Special Exposure Cohort). The compensation decision for cancer claimants is based on a section of the statute entitled "Exposure in the Performance of Duty." That provision [42 U.S.C. § 7384n(b)] says that an individual with cancer "shall be determined to have sustained that cancer in the performance of duty for purposes of the compensation program if, and only if, the cancer … was at least as likely as not related to employment at the facility [where the employee worked], as determined in accordance with the POC [probability of causation[1]] guidelines established under subsection (c) …" [42 U.S.C. § 7384n(b)]. Neither the statute nor the probability of causation guidelines (nor the dose reconstruction regulation) define "performance of duty" for DOE employees with a covered cancer or restrict the "duty" to nuclear weapons work.

As noted above, the statute includes a definition of a DOE facility that excludes "buildings, structures, premises, grounds, or operations covered by Executive Order No. 12344, dated February 1, 1982 (42 U.S.C. 7158 note), pertaining to the Naval Nuclear Propulsion Program" [42 U.S.C. § 7384l(12)]. While this definition contains an exclusion with respect to the Naval Nuclear Propulsion Program, the section of EEOICPA that deals with the compensation decision for covered employees with cancer [i.e., 42 U.S.C. § 7384n(b), entitled "Exposure in the Performance of Duty"] does not contain such an exclusion. Therefore, the statute requires NIOSH to include all occupationally derived radiation exposures at covered facilities in its dose reconstructions for employees at DOE facilities, including radiation exposures related to the Naval Nuclear Propulsion Program. As a result, all internal and external dosimetry monitoring results are considered valid for use in dose reconstruction. No efforts are made to determine the eligibility of any fraction of total measured exposure for inclusion in dose reconstruction. NIOSH, however, does not consider the following exposures to be occupationally derived:

- Radiation from naturally occurring radon present in conventional structures
- Radiation from diagnostic X-rays received in the treatment of work-related injuries

[1] The U.S. Department of Labor is ultimately responsible under the EEOICPA for determining the POC.

1.1.1 Purpose

The purpose of this Introduction is to provide a summary of the contents of the five technical basis documents (TBDs) that, along with this Introduction, constitute the Hanford Site Profile.

1.1.2 Scope

The Site Profile is divided into this Introduction and five major TBDs: Site Description, Occupational Medical Dose, Occupational Environmental Dose, Occupational Internal Dose, and Occupational External Dosimetry.

1.2 DISCUSSION

This Hanford Site Profile provides supporting technical data to evaluate, with assumptions favorable to claimants, the total Hanford occupational radiation dose that can reasonably be associated with a worker's radiation exposures. This dose results from exposure to external and internal radiation sources in Hanford facilities, to Hanford occupationally required diagnostic X-ray examinations, and to onsite environmental releases. In addition, the Site Profile examines the dose that could have occurred while the worker was not monitored or dose that could have been missed. Over the years since operations at Hanford began, new and more reliable scientific methods and protection measures have been developed. The methods needed to account for these changes are identified in this Site Profile.

This Site Profile can be a tool when performing dose reconstructions for Hanford workers. The Integrated Modules for BioAssay Analysis (IMBA) computer program is a tool useful for internal dose calculations. Information on measurement uncertainties is an integral component of the NIOSH approach. This document describes how to evaluate uncertainty associated with Hanford exposures and dosimetry records.

The Site Description TBD (ORAUT 2004a) briefly describes the facilities and processes used in the development of nuclear weapons and other programs at Hanford since the early 1940s.

Over time, there were more than 500 facilities on the 600-mi^2 Hanford Site that contributed to the mission of producing plutonium, uranium, tritium, and other radionuclides that contributed not only to the weapons program but also to the space program and the medical profession. These facilities were used for radiation effects studies, nuclear physics research and development, criticality studies, calibrations, radiochemistry development, radiometallurgy, biochemistry, process equipment development, and many other applications.

Beginning in 1944, the Hanford Site operated nine production reactors to produce plutonium by the irradiation of metallic uranium fuel elements. In addition to the plutonium production, Hanford conducted experiments on other defense-related radionuclides such as the irradiation of thorium to produce ^{233}U, depleted uranium to produce ^{240}Pu, neptunium targets to produce ^{238}Pu, and americium to produce medical-grade ^{238}Pu.

In addition to the production reactors, there were seven testing, research, and demonstration reactors used for testing fuel elements and fuel configurations, measuring changes due to various types of fuel elements, measuring the thermal impact on fission cross-sections, studying reactor physics technology, performing long-term testing of reactor materials, producing medical radioisotopes, and researching power systems for use in space (ORAUT 2004a).

The reactor products had to be chemically separated for use in the weapons program. These chemical separations were done in the T- and B-Separations Canyons. The complex chemical and physical processes performed in these canyons separated uranium, plutonium, and fission products. Plutonium was separated from the uranium and fission products by a bismuth-phosphate precipitation batch process. Additional processing resulted in the desired final plutonium product. The chemical separations processes changed over the years from the bismuth-phosphate precipitation process to the reduction oxidation (REDOX) process to the plutonium-uranium extraction (PUREX) process. Both the REDOX and PUREX processes used organic solvent extraction processes. Each process improved the recovery of uranium, plutonium, and other radionuclides such as neptunium (ORAUT 2004a).

In addition to the production and separations facilities, there were three facilities for fuel fabrication: the Uranium Metal Fuels Fabrication facility, the Uranium Metal Extrusion facility, and the Fuel Cladding facility. There were also two support facilities, the Uranium Storage and Oxide Burner facility and the Reactor Fuel Manufacturing Pilot Plant (ORAUT 2004a).

Waste handling facilities were present on the site to handle the high- and low-level radioactive wastes that the various processes produced. The U-Plant was used for the recovery of uranium from high-level liquid wastes from the B- and T-Plants. The U-Plant operated from 1952 until January 1958. Other facilities were built to support the separations processes for uranium, plutonium, neptunium, and tritium (ORAUT 2004a).

The Occupational Medical Dose TBD (ORAUT 2005) provides information about the doses that individual workers received from X-rays required as a condition of employment. These included preemployment and annual chest X-rays during physical examinations. The frequency of required X-rays varied over time and as a function of the worker's age. All workers received annual chest X-rays from August 1945 to 1959. From April 12, 1959, to January 28, 1983, workers over 50 years of age received annual X-rays, while workers from 40 to 49 received X-rays biennially, and those under the age of 40 received an X-ray every 3 years. This frequency changed from January 28, 1983, to March 30, 1990, during which time employees over 50 received an X-ray biennially, those 40 to 49 every third year, and the under 40 age group every fifth year. From March 30, 1990, to April 22, 1997, all employees received an X-ray every fifth year. From April 22, 1997, to the present, X-rays have been given only as required.

Both the X-ray equipment and the techniques used for taking X-rays covered by this TBD have changed over the years. These factors have been taken into account in determining the dose that a worker would have received from the X-ray. Where there was doubt about the technique used, assumptions favorable to claimants were made to ensure that the worker's dose would not be underestimated. The investigated parameters include the tube current and voltage, exposure time, filtration, source to skin distance, the view (posterior-anterior or lateral), and any other factor that could affect the dose received by the worker.

The doses to other exposed organs from chest X-rays have also been calculated. The calculated doses take into account the uncertainty associated with each of the parameters. Tables in ORAUT (2005) list the doses received by the various organs in the body as a convenient reference for the dose reconstructors.

The Occupational Environmental Dose TBD (ORAUT 2006a) applies to workers who were not monitored for external or internal radiation exposures. The environmental dose is the dose workers received when working on the site but outside the buildings from inhalation of radioactive materials in

the air, direct radiation from plumes, contact with particles on the skin, and direct exposure to radionuclides that could have become incorporated in the soil (ORAUT 2006a).

Exposure to these sources can result in an internal dose to the whole body or body organs from inhalation of radioactive materials, and it can result in a whole- or partial-body external dose from radionuclides deposited on the skin or submersion in the cloud of radioactive material.

The radionuclide concentrations at Hanford are based on the source terms developed by others. Screening studies have demonstrated that ^{131}I, ^{41}Ar, ^{144}Ce-^{144}Pr, ^{137}Cs, ^{239}Pu, ^{103}Ru-^{103}Rh, ^{106}Ru-^{106}Rh, ^{90}Sr, and ^{90}Sr-^{90}Y contributed the greatest doses to site workers. This TBD discusses the solubilities of several of these radionuclides.

Intakes of radionuclides by workers at specific locations on the Site were calculated using the Regional Atmospheric Transport Code for Hanford Emission Tracking (RATCHET) computer program and a spreadsheet. Attachment A to this TBD lists these intake data along with source term data and submersion doses.

The external dose to workers from the ambient radiation levels on the Site and from submersion in a cloud of radioactive material are presented along with the skin dose from the ^{41}Ar.

The Occupational Internal Dose TBD (ORAUT 2004b) discusses the internal dosimetry program at the Hanford reservation. From the beginning of Hanford operations in 1943 until 1946, personnel monitoring was the responsibility of the Medical Department. At that time, there was no bioassay program to determine the internal dose that workers could have received. Therefore, assumptions favorable to claimants have been made to provide the dose reconstructors with the ability to determine a worker's dose in this early period. Later, the bioassay program was developed and constantly improved over the years as technology progressed. Electronic databases were developed to maintain urinalysis records. These are discussed along with the various codes used to identify the specific analysis performed.

This TBD discusses the *in vitro* minimum detectable activities (MDAs), the analytical methods, and the reporting protocols for the radionuclides at Hanford. These parameters varied over the years for each of the evaluated radionuclides, which included those of plutonium, americium, curium, tritium, uranium, strontium, promethium, polonium, neptunium, and fission products. This TBD discusses these issues in detail.

In addition, this TBD discusses the *in vivo* MDAs, the analytical methods, and the reporting protocols for the X- and gamma-ray emitting radionuclides. The *in vivo* measurement equipment and techniques were developed in the late 1950s and have been in routine use at Hanford since 1960. Detailed discussions are presented for the use of the whole-body counter, the radionuclides for which it was used, the radionuclide-specific MDAs, and the reporting levels for the various periods during which these parameters changed. There are similar discussions of the *in vivo* chest counters, thyroid counters, and head counters. Detailed information is provided in a database to assist the dose reconstructors in interpreting data they might encounter in the worker's records.

The TBD discusses information on the specific radionuclides in each of the various facilities to which the workers could have been exposed. Information is provided for the periods when processes changed as a result of improvements in the processing systems.

Interferences that could have been encountered in the collection and analysis of bioassay samples are discussed, as are the uncertainties in the bioassay measurements. Information is presented for

workers who could have been exposed, but for whom there are no confirmed intakes because of the detection capabilities or the sampling techniques used at the time or because there were missed samples. Methods for evaluating doses that could fall in this category are presented. Additional data are provided for the evaluation of the worst-case scenario and for unmonitored workers.

Many tables are provided in Attachment D to aid the dose reconstructor in evaluating the potential doses received by workers under all circumstances (ORAUT 2004b).

The Occupational External Dosimetry TBD (ORAUT 2006b) discusses the program for measuring skin and whole-body doses to the workers. As with internal dosimetry, the methods for evaluating external doses to workers have evolved over the years as new techniques and equipment have been developed and as the concepts in radiation protection have changed. The dose reconstruction parameters, Hanford practices and policies, and dosimeter types and technology for measuring the dose from the different types of radiation are discussed in this section. Attention is given to the evaluation of doses measured from exposure to beta, gamma, and neutron radiation. Tables show test results for various dosimeters exposed to different exposure geometries and radiation energies.

Sources of bias, workplace radiation field characteristics, responses of the different beta/gamma and neutron dosimeters in the workplace fields, and the adjustments to the recorded dose measured by these dosimeters during specific years are discussed in detail.

There are sources of potential dose that could be missed because of the limitations of dosimetry systems and the methods of reporting low doses. These potentially missed doses are discussed as a function of facility location, dosimeter type, year, and energy range. Attachment E to this TBD describes the use of the external dosimetry technical basis parameters to facilitate the efforts of the dose reconstructors (ORAUT 2006b).

1.3 ATTRIBUTIONS AND ANNOTATIONS

All information requiring identification was addressed via references integrated into the reference section of this document.

REFERENCES

ORAUT (Oak Ridge Associated Universities Team), 2004a, *Technical Basis Document for the Hanford Site – Site Description*, ORAUT-TKBS-0006-2, Rev. 00 PC-1, Oak Ridge, Tennessee, December 29.

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