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| <p>ORAU Team NIOSH Dose Reconstruction Project</p> <p>Technical Basis Document for the Hanford Site – Introduction</p> | <p>Document Number: ORAUT-TKBS-0006-1 Effective Date: 11/07/2003 Revision No.: 00 Controlled Copy No.: _____ Page 1 of 7</p> |
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ACRONYMS AND ABBREVIATIONS

EEOICPA Energy Employees Occupational Illness Compensation Program Act of 2000

MDA minimum detectable activity

NIOSH National Institute for Occupational Safety and Health

ORAU Oak Ridge Associate Universities

TBD technical basis document

In enacting the Energy Employees Occupational Illness Compensation Program Act of 2000 (EEOICPA), the U.S. Congress officially recognized the hazardous nature of producing and testing nuclear weapons. Under the Act, workers who have developed selected types of cancer (or their survivors) may be entitled to compensation and medical benefits. This program is administered by the U.S. Department of Labor Office of Worker Compensation. The National Institute for Occupational Safety and Health (NIOSH), a part of the U.S. Department of Health and Human Services, is responsible for determining the individual worker's dose. Oak Ridge Associated Universities (ORAU) leads a team to support NIOSH in conducting this major program.

The Act requires the estimation of radiological doses from ionizing radiation received by workers in the nuclear weapons production programs of the U.S. Department of Energy and its predecessor agencies. Methods for implementing provisions of the Act have been promulgated in Title 42 of the Code of Federal Regulations, Part 82, "Methods for Radiation Dose Reconstruction Under the Energy Employees Occupational Illness Compensation Program Act of 2000."

This technical basis document (TBD) is a specific support mechanism to the ORAU Team concerning documentation of historical practices at the Hanford Site. Dose reconstructors should use the information in this TBD to evaluate both internal and external dosimetry data for unmonitored and monitored workers. In addition, the document serves as a supplement to, or a substitute for, individual monitoring data. This document provides a site profile of Hanford that contains technical basis information for the ORAU Team to use to evaluate the total occupational radiation dose for EEOICPA claimants.

In addition, this document provides supporting technical data to evaluate, with claimant-favorable assumptions, the total Hanford occupational radiation dose that can reasonably be associated with worker 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 on-site environmental releases. The discussion includes the doses that workers could have incurred while not monitored or that could have been missed.

Over the years new and more reliable scientific methods and protection measures have been developed. The methods needed to account for these changes are also identified in this document.

The doses are to be evaluated using the NIOSH Interactive RadioEpidemiological Program (IREP) and the Integrated Modules for Bioassay Analysis (IMBA) computer programs. Information on measurement uncertainties is an integral component of the NIOSH approach. This document describes how the uncertainty for Hanford exposure and dose records is to be evaluated.

The document comprises six sections: this introduction, Site Description, Occupational Medical Dose, Occupational Environmental Dose, Occupational Internal Dose, and Occupational External Dosimetry. Some sections are accompanied by an attachment that provides the critical data for the specialists reconstructing the doses.

Section 2, Site Description, briefly describes the facilities and processes that have been used in the development of nuclear weapons since the early 1940s.

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

In addition to the production reactors, there were seven physical testing, research, and demonstration reactors 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 space power systems.

The reactor products had to be separated chemically for use in the weapons program. These chemical separations were done in the T and B Separations Canyons. The complex chemical and physical processes 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 REDOX and PUREX used organic solvent extraction processes. Each process improved the recovery of uranium, plutonium, and other radionuclides (such as neptunium).

The U plant was another facility that was used for the recovery of uranium from high-level liquid waste from the B and T Plants. The U Plant operated from 1952 until January 1958.

Various other facilities were built to support the separations process for uranium, plutonium, neptunium, and tritium.

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 two support facilities: the Uranium Storage and Oxide Burner facility and the Reactor Fuel Manufacturing Pilot Plant.

In total, there were more than 500 facilities on the 600-mi² Hanford site that contributed to the mission of producing plutonium, uranium, tritium, and other radionuclides not only for the weapons program but also for 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.

Waste handling facilities on the site handled the high- and low-level radioactive wastes produced in the various processes mentioned above.

Section 3 Occupational Medical Dose, provides information about the dose that individual workers received from X-rays that were required as a condition of employment. These X-rays included pre-employment and annual chest X-rays during physical exams.

The frequency of required X-rays varied over time and as a function of worker age. All workers received annual chest X-rays from before 1946 through 1959. From April 12, 1959, through January 28, 1983, workers over 50 years of age received annual X-rays, while workers in the 40 to 49 age group 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 years of age received an X-ray biennially, the 40 to 49 age group received one every 3 years, and the under-40 age group received one every 5 years. From March 30, 1990, to April 22, 1997, all employees received an X-ray every 5 years. 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 have changed over the years covered by this TBD. These factors have been taken into account in determining the dose that a worker would have received from an X-ray. When there was a doubt about the technique used, the most claimant-favorable assumptions have been made to ensure that the dose is not 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 the chest X-ray have also been calculated. The calculated dose takes into account the uncertainty associated with each of the parameters mentioned above. Tables present the doses received by the various organs for convenient reference by the dose reconstructors.

Section 4, Occupational Environmental Dose, applies to workers who were not monitored for external or internal radiation exposure. The environmental dose is the dose workers receive when working outside the buildings on the site from inhalation of radioactive materials in the air, direct radiation from plumes, contact with particles on the skin, and from direct exposure to radionuclides in the soil.

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

The radionuclide concentrations in Hanford areas 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 , ^{90}Sr - ^{90}Y have contributed the greatest dose to site workers. In addition, this section discusses the solubility of several of these radionuclides.

Intakes of radionuclides by workers at specific locations on the site were calculated using the RATCHET computer program and an Excel spreadsheet. These data are presented in Attachment A of this section along with source term data and submersion doses.

In addition, the section discusses the external dose to workers from ambient radiation levels on the site and from submersion in a cloud of radioactive material, along with the skin dose from ^{41}Ar .

Section 5, Occupational Internal Dose, discusses the internal dosimetry program at the Hanford reservation. Initially (1943 to 1946) personnel monitoring was the responsibility of the Medical Department. At that time, there was no bioassay program to determine the internal dose workers may have received. Therefore, claimant-favorable assumptions have been made to provide the dose reconstructors with the ability to determine a worker's dose during this early period. The bioassay program was later developed and constantly improved over the years as technology progressed. Electronic databases were developed to maintain urinalysis records. In addition, this section discusses the various codes used to identify the specific analysis performed.

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

In addition, this section 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. There are detailed discussions of 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 the database to assist the dose reconstructors in interpreting data they may encounter in the worker's records.

Discussions provide information on the specific radionuclides to which the workers in each of the various facilities could have been exposed. In addition, the section provides information for the periods of time when processes changed as a result of improvements in the processing systems.

Interferences that may be encountered in the collection and analysis of bioassay samples are discussed, as are the uncertainties in the bioassay measurements. Information is presented for workers with no confirmed intakes, but who may have been exposed in the early days when the detection capability and sampling techniques were poor or there were missed samples. Methods for evaluating potential doses that may fall in this category are presented. Additional data are provided for the evaluation of the worst case scenario and for unmonitored workers.

Attachment D provides many tables to aid the dose reconstructor in evaluating the potential doses received by workers under all circumstances.

Section 6, Occupational External Dosimetry, discusses the program for measuring skin and whole-body doses to the workers. The methods for evaluating external doses to workers have also evolved over the years as new techniques and equipment have been developed. In addition, concepts in radiation protection have changed. The dose reconstruction parameters, Hanford practices and policies, and dosimeter types and technologies for measuring the dose from the different types of radiation are discussed. Attention is given to the evaluation of doses measured from exposure to beta, gamma, and neutron radiation. Tables present 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 have been missed because of the limitations of dosimetry systems and the methods of reporting low doses. This missed dose is discussed as a function of facility location, dosimeter type, year, and energy range. Attachment E describes the use of the external dosimetry technical basis parameters to facilitate the efforts of the dose reconstructors.