



## ORAU TEAM Dose Reconstruction Project for NIOSH

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### PUBLICATION RECORD

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**ACRONYMS AND ABBREVIATIONS**

DOE	U.S. Department of Energy
EEOICPA	Energy Employees Occupational Illness Compensation Program Act of 2000
kerma	kinetic energy released per unit mass
NIOSH	National Institute for Occupational Safety and Health
PGDP	Paducah Gaseous Diffusion Plant
POC	probability of causation
TBD	technical basis document
U.S.C.	United States Code
§	section or sections

## 1.1 PURPOSE

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 historical 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<sup>1</sup>] 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

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<sup>1</sup> The U.S. Department of Labor is ultimately responsible under the EEOICPA for determining the POC.

## 1.2 SCOPE

The Paducah Gaseous Diffusion Plant (PGDP) Site Profile is divided into six major sections – this Introduction, Site Description, Occupational Medical Dose, Occupational Environmental Dose, Occupational Internal Dose, and Occupational External Dose. Some sections are accompanied by an attachment that provides the critical data for the specialists reconstructing the doses.

The Site Description TBD (ORAUT 2006a) is a brief description of the facilities and processes that PGDP used to process and enrich uranium. The purpose of the gaseous diffusion plant has been and continues to be the enrichment of uranium, initially for military applications and subsequently for commercial nuclear reactor fuel. PGDP enriches feed material in the form of uranium hexafluoride gas ( $UF_6$ ) from approximately 0.711%  $^{235}U$  up to about 2.5%  $^{235}U$ . The enriched product from PGDP has been sent to other U. S. Department of Energy (DOE) gaseous diffusion plants at Portsmouth, Ohio, and Oak Ridge, Tennessee, for further enrichment. Some feed material was recycled uranium from spent reactor fuel.

The Occupational Medical Dose TBD (ORAUT 2006b) provides information about the doses individual workers received from X-rays that were required as a condition of employment. The PGDP occupational medicine program required preemployment and regular diagnostic chest X-ray examinations. The examinations consisted of one posterior-anterior and one lateral chest projection. In addition to parts of the body exposed in the primary beam of an X-ray machine, other tissues received some dose from secondary radiation. Secondary radiation consists of X-rays that are scattered from surrounding materials or that escape from the source assembly. This TBD provides tables that list estimated dose equivalents to organs of the body that result from single and combined posterior-anterior and lateral chest X-rays for male and female PGDP employees; these estimates are favorable to claimants. The tables are derived from an assessment of the air kerma at the source-to-skin distance based on specific operating parameters for the facility, insofar as these are known.

The Occupational Environmental Dose TBD (ORAUT 2006c) applies to workers who were not monitored for external or internal radiation exposure. 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 and direct radiation exposure from sources such as the depleted uranium hexafluoride cylinders in storage.

Inhalation of environmental radionuclides results in internal dose to the whole body or body organs. The internal dose for workers outside of the facilities was determined from the air concentrations that were a result of the releases from stacks, individual building releases, and from the purge cascade and other operations at PGDP. Unmonitored workers might have been incurred occupational doses internally from onsite releases to the air. Air concentrations of radionuclides were determined using annual environmental reports for the period from 1952 through 1996. Values for airborne concentrations and annual intakes are provided for total uranium and  $^{99}Tc$ .

Site annual environmental reports, health physics surveys, and other reports were reviewed for data that would be useful in reconstructing ambient radiation levels. Ambient radiation dose rates include natural background radiation and sources within the site.

PGDP personnel have annually compared these data with thermoluminescent dosimeter data from offsite locations and literature values for State of Kentucky and regional exposure levels. The determination has always been that onsite ambient radiological conditions as measured at the security fence are not significantly different from offsite, State, and regional annual exposure levels. This is attributed to the geology of the region around PGDP. Exceptions to this observation have

been monitoring locations near depleted uranium cylinder storage yards in recent years. These locations have shown increases in external exposure as the inventory of depleted uranium has increased. The approach for estimating external dose using this information is provided in the TBD.

The Occupational Internal Dosimetry TBD (ORAUT 2007) describes the internal dosimetry program at PGDP. The primary method for monitoring employees for intakes of radionuclides at PGDP was urine bioassay, which was instituted at the start of enrichment operations and has continued to the present day. However, the focus of the monitoring program in the early years was the detection of excreted soluble uranium. When monitoring for less soluble isotopes of uranium and transuranic elements was necessary, *in vivo* methodologies were implemented to supplement the excretion data. These methods were primarily whole-body counting and chest (lung) counting.

Until the mid-1980s, action levels were set based on the amount of uranium excreted. Later, intakes and doses were assessed based upon both *in vivo* and *in vitro* monitoring results. Data are available from 1952 to the present for both *in vivo* and *in vitro* analysis records and associated interpretations.

A review of in-house procedures used to assess the concentration of uranium in urine indicates that a variety of quality control steps were an integral part of the process. Therefore, the *in vitro* results from in-house processing, typically reported in units of micrograms of uranium per liter, are considered to be generally reliable. However, interpretation of those results can be difficult primarily because of uncertainties about enrichment and solubility, the contribution of environmental uranium, and because samples were collected at work and during the middle of the work week, meaning that cross-contamination and the inability to separate soluble and insoluble intake fractions.

Guidance on selection of source terms is provided in the TBD. Input parameters for the interpretation of *in vivo* and *in vitro* measurement results are presented and include instructions for assessing dose for both monitored and unmonitored employees. The detection limits of the various *in vivo* and *in vitro* methodologies and potential missed dose are discussed. Existing data analysis is summarized, and significant incidents with internal dose potential are identified.

The Occupational External Dosimetry TBD (ORAUT 2006d) describes the program for measuring skin and whole-body doses to the workers from sources that were external to the body. The methods used at the PGDP have also evolved over the years as new techniques and equipment have been developed. In addition, concepts in radiation protection have changed. Dose reconstruction, PGDP 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.

Sources of bias, workplace radiation field characteristics, responses of 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 presented in detail. In addition, the sources of potential dose that could be missed because of the limitations of dosimetry systems and the methods of reporting low doses are presented as a function of dosimeter type, year, and type of radiation.

### **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), 2006a, *Paducah Gaseous Diffusion Plant – Site Description*, ORAUT-TKBS-0019-2, Rev. 01, Oak Ridge, Tennessee, August 21.
- ORAUT (Oak Ridge Associated Universities Team), 2006b, *Paducah Gaseous Diffusion Plant – Occupational Medical Dose*, ORAUT-TKBS-0019-3, Rev. 01, Oak Ridge, Tennessee, September 26.
- ORAUT (Oak Ridge Associated Universities Team), 2006c, *Paducah Gaseous Diffusion Plant – Occupational Environmental Dose*, ORAUT-TKBS-0019-4, Rev. 01, Oak Ridge, Tennessee, November 7.
- ORAUT (Oak Ridge Associated Universities Team), 2006d, *Paducah Gaseous Diffusion Plant – Occupational External Dose*, ORAUT-TKBS-0019-6, Rev. 02, Oak Ridge, Tennessee, August 30.
- ORAUT (Oak Ridge Associated Universities Team), 2007, *Paducah Gaseous Diffusion Plant – Occupational Internal Dose*, ORAUT-TKBS-0019-5, Rev. 01 PC-1, Oak Ridge, Tennessee, January 31.