
Technical Basis for Internal Dosimetry at Hanford

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July 1991

**Prepared for the U.S. Department of Energy
under Contract DE-AC06-76RLO 1830**

**Pacific Northwest Laboratory
Operated for the U.S. Department of Energy
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PACIFIC NORTHWEST LABORATORY
operated by
BATTELLE MEMORIAL INSTITUTE
for the
UNITED STATES DEPARTMENT OF ENERGY
under Contract DE-AC06-76RLO 1830

Printed in the United States of America

Available to DOE and DOE contractors from the
Office of Scientific and Technical Information, P.O. Box 62, Oak Ridge, TN 37831;
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ABSTRACT

The Hanford Internal Dosimetry Program, administered by Pacific Northwest Laboratory^(a) for the U.S. Department of Energy, provides routine bioassay monitoring for employees who are potentially exposed to radionuclides in the workplace. This report presents the technical basis for routine bioassay monitoring and the assessment of internal dose at Hanford. The radionuclides of concern include tritium, corrosion products (^{58}Co , ^{60}Co , ^{54}Mn , and ^{59}Fe), strontium, cesium, iodine, europium, uranium, plutonium, and americium. Sections on each of these radionuclides discuss the sources and characteristics; dosimetry; bioassay measurements and monitoring; dose measurement, assessment, and mitigation; and bioassay follow-up treatment.

(a) Pacific Northwest Laboratory is operated by Battelle Memorial Institute for the U.S. Department of Energy under Contract DE-AC06-76RLO 1830.

ACKNOWLEDGMENTS

In the production of this report, the authors gratefully acknowledge the invaluable support of R. J. Traub as peer reviewer, S. K. Ennor as editor, and Marge Johnston, Marianna Cross, Rose Moreno, and Margot White as word processors.

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ACRONYMS LIST

ALARA	as low as reasonably achievable
ALI	annual limit on intake
AMAD	activity median aerodynamic diameter
ANSI	American National Standards Institute
BS	bone surface
DCF	dose conversion factor
D&D	decontamination and decommissioning
DIL	derived investigation level
DOE	U.S. Department of Energy
DTPA	diethylene triamine penta acetate
D,W,Y	days, weeks, years (lung classes)
EDE	effective dose equivalent
EDF	Emergency Decontamination Facility
EDTA	ethylene diamine tetraacetic acid
EPA	Environmental Protection Agency
FETF	Fast Flux Test Facility
FPF	Fuel Production Facility
FPF-RU	Fuel Production Facility recycled uranium
FY	fiscal year
GI	gastrointestinal
HEHF	Hanford Environmental Health Foundation
IAEA	International Atomic Energy Agency
ICRP	International Commission on Radiological Protection
IG	intrinsic germanium
IVRRF	In Vivo Radioassay and Research Facility
LLI	lower large intestine
MDA	minimum detectable activity (or amount)
MKIV	Mark IV
MPBB	maximum permissible body burden
NA	not applicable
NBS	National Bureau of Standards
NCRP	National Council on Radiation Protection and Measurements
N-P	nasal passage region of the respiratory tract
P	pulmonary region of the lung
PNL	Pacific Northwest Laboratory
ppmp	parts per million per ...
ppbp	parts per billion per ...

PUREX Plutonium Uranium Extraction (Facility)

RM red marrow
RPS radiation protection standard

SEE specific effective energy
SI small intestine

TAT threshold for acute toxicity
T-B tracheal-bronchial region of the lung
TGLD Task Group on Lung Dynamics

ULI upper large intestine
UO3 Uranium Oxide (Plant)
UO3-RU Uranium Oxide Plant recycled uranium

WBC whole body counter
WESF Waste Encapsulation and Storage Facility

MATHEMATICAL SYMBOLOGY^(a)

$C(t)$	body water concentration of tritium at time t post intake
$e^a(t)$	fractional excretion based on the fraction of uptake to blood
$e^a_u(t)$	fractional uptake urinary excretion
$e^a_u(t)$	fractional intake urinary excretion
$H_{T,t}$	tissue dose equivalent in year t post intake
$H_{T,1}$	first-year tissue dose equivalent
$H^c_{T,t}$	cumulative or committed tissue dose equivalent through year t post intake
$H_{E,t}$	effective dose equivalent in year t post intake
$H^c_{E,50}$	50-year committed effective dose equivalent
I	intake
L_c	decision level; the level above which an analyte is determined to be present in a sample
$M_u(t)$	measured urinary excretion at time T (not fractional)
$Q(t)$	the retained quantity at time t (not fractional)
$r^a_s(t)$	fractional uptake systemic retention at time t including systemically fed organs and tissues
$U(t)$	uptake through time t
$U(\infty)$	total uptake. Note: concerning uptake to blood, $U(\infty)$ is the presystemic deposition
W_T	effective dose equivalent weighting factor for tissue T
X_i	result of a measurement
σ_i	uncertainty associated with the result X_i

(a) The symbology used in this document generally follows that used in Publication 54 of the International Commission on Radiological Protection (1988).

GLOSSARY

annual effective dose equivalent, H_E : the sum of the products of the annual tissue dose equivalent, H_T , to organs and tissues of the body and the respective weighting factors as designated in DOE 5480.11 (DOE 1988).

annual tissue dose equivalent, H_T : unweighted dose equivalent to a specific organ or tissue.

a priori: presupposed by experience. In the context of counting statistics, it refers to estimated or general capabilities determined prior to an actual sample count.

bioassay: measurement of amount or concentration of material (usually radioactive material) in the body or in biological material excreted or removed from the body and analyzed for purposes of estimating the quantity of material in the body (from ANSI 1987).^(a)

burden: the instantaneous activity of a radionuclide in a systemically fed organ or tissue, the lung, or in the whole body excluding the activity at the entry site and lymph system (lung, wound site, and/or in material passing through the GI tract.) For nontransportable activity obtained by inhalation, both the body burden and the lung burden would be required to completely characterize the situation at a given time. Using ICRP 54 (1988) terminology, burden is the same as retained quantity.

committed: refers to a total or time-integrated amount for 50 years post intake or onset of a chronic intake (or for a different period if so specified).

committed dose equivalent, $H^C_{T,50}$: dose equivalent to a organ or tissue committed for a 50-year period following an acute intake or onset of chronic intake. It does not include contributions from external dose (DOE 1988).

committed effective dose equivalent, $H^C_{T,50}$: the effective dose equivalent committed for a 50-year period following an acute intake or onset of chronic intake. It does not include contributions from external dose (DOE 1988).

corrosion products: elements that are present in the structure of the reactor or the fuel rods that become activated by neutrons, as opposed to fission products that result from fission.

(a) American National Standards Institute (ANSI). 1987. Performance Criteria for Radiobioassay. Draft ANSI Standard N13.30, New York, New York.

deposition: the total input to an organ or tissue for a specified period of time. Deposition can also refer to material deposited at an entry site. See also systemic deposition.

detection level: a general term relating to the smallest amount of material detectable as a function of the measurement method and instrument background. (The precise way that detection level has been defined has changed over the years.)

detection limit: synonymous with detection level.

injection: any means whereby the radioactive material is placed in direct contact with the blood, excluding through the lung or GI tract.

intake: the amount of material taken into the body by inhalation, absorption through the skin, injection, ingestion or through wounds (from NCRP 1987).

in vivo: refers to measuring radioactivity directly on a living organism. In vivo is synonymous with the word "direct" when used in the phrase "direct bioassay".

minimum detectable activity, MDA: the smallest activity of a radionuclide in a sample (or organ) that will be detected with a specified level of confidence. See Appendix C for details.

positive level: a level of a bioassay measurement at which the Hanford Internal Dosimetry Program considers the analyte to be detected (as opposed to being detectable).

presystemic deposition: a mathematical or schematic component (or components) of the deposition at the entry site that is available for translocation to the blood. It excludes material that is permanently retained at the entry site or by the lymph system.

preview counter: a standup whole body counter consisting of 5 NaI detectors. It is the principal counter used for routine whole body counts and incident screening counts, provided good resolution of photopeaks is not needed.

readily transportable: being readily transferred from the site of initial deposition to the blood. As applied to material in the lung, readily transportable material would be class D. It is generally equivalent to the term "soluble" as applied to human physiology, but it is not necessarily equivalent to chemical solubility in aqueous solutions.

retained quantity: synonymous with burden.

retention: the retained quantity (or burden) as a fraction of the uptake or intake. It can apply to an organ or to the whole body.

specific effective energy, SEE: the energy, suitably modified for quality factor, imparted per gram of a target tissue as a consequence of the emission of a specified radiation from a transformation occurring in a source tissue. The units are Mev per gram-transformation (from ICRP 1979).

super Y: an inhalation class in which the radioactive material is more tenaciously retained in the pulmonary region of the lung than class Y material; i.e., the clearance half-time from the pulmonary region of the lung is greater than 500 days. For purposes of prospective analyses in this document, super Y was assumed to be characterized by a 10,000-day clearance half-time for pathways a, c, e, and i as shown in Figure D.1.

systemic deposition: activity retained for an extended period of time in all systemic organs and tissue. Differs from uptake in that activity that stays in the transfer compartment and is ultimately excreted without going to systemic organs (for instance, because of chelation) is included in the term uptake but not in the term systemic deposition.

time-integrated activity or cumulative activity: the integral over time of the instantaneous activity in an organ or in the whole body. The units are activity times time, such as nanocurie-days. When multiplied by the SEE factor and appropriate unit conversion factors, the time-integrated activity provides the dose equivalent to the target organ.

transfer compartment: a mathematical or schematic representation of the blood circulation system through which radioactive material is transported to organs, tissues, or excretion.

uptake: quantity of a radionuclide taken up by the systemic circulation, e.g., by injection into the blood, by absorption from compartments in the respiratory or GI tracts, or by absorption through the skin or through wounds in the skin (from NCRP 1987), or taken up by a specified organ or tissue via the blood.

SECTION 1.0

INTRODUCTION

1.0 INTRODUCTION

The Hanford Internal Dosimetry Program, administered by Pacific Northwest Laboratory (PNL) for the U.S. Department of Energy (DOE), provides internal dosimetry support services for operations at the Hanford Site. These operations include the production and purification of plutonium, the fabrication of uranium fuel elements, the operation of large thermal (presently in standby status) and fast reactors, the processing of radioactive wastes, and research and development.

Nearly 8,000 of the approximately 15,000 workers employed at Hanford by DOE and its contractors participate in routine bioassay monitoring programs. Radionuclides of particular interest are the fission and activation product radionuclides, uranium, and plutonium.

This report describes the technical basis for the design of the routine bioassay monitoring program and upon which assessment of internal dose is performed. The purposes of this report are to:

- provide assurance that the Hanford Internal Dosimetry Program derives from a sound technical base
- promote the consistency and continuity of routine program activities
- provide a historical record
- serve as a technical reference for radiation protection personnel
- aid in identifying and planning for future needs.

Internal dosimetry at Hanford is based on the concepts of effective dose equivalent described in Publications 26 and 30 of the International Commission on Radiological Protection (ICRP 1977, 1979) and modified to apply to annually received dose as prescribed by DOE 5480.11 (DOE 1988). The annually received effective dose equivalent is the basis for evaluating compliance with regard to the 5 rem/yr DOE Radiation Protection Standard (RPS). Fifty-year committed dose equivalents (both tissue and effective dose equivalents) are also calculated and reported.

1.1 DOCUMENT DESCRIPTION

This document consists of a number of sections and appendixes. Each section deals with a specific radionuclide or a related group of radionuclides. The appendixes provide information that is general to all of the sections. Radionuclides not specifically mentioned are rarely encountered in amounts of dosimetric concern. The basis for dosimetry for other radionuclides will be added to this document (as revisions) if the need arises.

This document was first issued in April 1989. In its first 2 years, the document found a wide audience among the DOE offices, its contractors, and other organizations involved in dosimetry. It not only served well as the intended reference for data, but became a template for other facilities in the development of their own technical basis documents.

This document is a "living" document responsive to the needs of the Hanford Internal Dosimetry Program. A limited number of documents are maintained under controlled distribution at Hanford for the convenience of those Hanford staff having direct responsibilities for site internal dosimetry. Uncontrolled copies are made available to other interested individuals.

1.2 REVISIONS

Revisions are made as needed, based on changes in the science and art underlying internal dose assessment, changes in the requirements of the program, and also to incorporate material found to be particularly useful for dose evaluation. These occasional revisions are made via Program Change Records maintained in the Hanford Radiation Protection Historical Files. Affected portions of the document are periodically revised and redistributed or the document is reissued in total as a numbered revision.

The extensive 1991 revision of the Technical Basis document was prompted by the desire to have certain additional information readily available for routine use in dose assessment and bioassay program design. Also, some changes in the presentation of information were identified to make the document easier to use, particularly in light of proposed performance standards for internal dosimetry. Advance drafts of the DOE Performance Standard for

Changes in the science and art of dosimetry are foreseeable in the future. Such changes might include a new lung model, improved biokinetic models for radionuclides in the body, new recommendations for organs of concern and weighting factors anticipated from ICRP, new implementing computer codes, and performance standards for internal dosimetry. However, at this time the existing "science" appears adequate for the stated purpose of the Hanford Internal Dosimetry Program, namely, evaluating compliance with applicable DOE standards for worker radiation protection as expressed in DOE 5480.11 (1988).

Changes have also occurred in the Hanford mission since the document was originally issued. With the phasing out of plutonium production, the need for dosimetry for freshly processed plutonium has decreased. Likewise, with N Reactor now in a cold-standby condition, uranium fuel production has ceased and the decay of relatively short-lived fission and activation products has substantially reduced the need for their dosimetry. The continued operation of the Fast Flux Test Facility warrants maintaining well-established internal dosimetry programs for these nuclides, however actual experience has shown little need for internal dose assessments associated with that facility. In addition, the potential need to review or reevaluate past cases of exposure to these nuclides warrants retaining the material in the Technical Basis document.