SEC Petition Evaluation Report
Petition SEC-00049

Report Rev #

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Petition Administrative Summary

Petition Under Evaluation

Petition #	Petition Type	Qualification Date	DOE/AWE Facility Name
SEC-00049	83.13	May 1, 2006	Monsanto Chemical Company

Petitioner Class Definition

Directors and subordinates, Physicists, Chemists, Technicians, Workers that worked at Monsanto Chemical Company in Dayton, Ohio during the period of 1943 to 1949.

Proposed Class Definition

All Atomic Weapons Employees who were monitored or who should have been monitored for radiation while working at Monsanto Chemical Company Units I, III, or IV in Dayton, Ohio for a number of work days aggregating at least 250 work days during the period of January 1, 1943 to December 31, 1949, or in combination with the work days within the parameters established for one or more other classes of employees in the Special Exposure Cohort.

Related Petition Summary Information

SEC Petition Tracking #(s)	Petition Type	DOE/AWE Facility Name	Petition Status
NA	NA	NA	NA

Related Evaluation Report Information

Report Title	DOE/AWE Facility Name
NA	NA

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Evaluation Report Summary: SEC-00049, Monsanto Chemical Company

This evaluation report by the National Institute for Occupational Safety and Health (NIOSH) addresses a class of employees proposed for addition to the Special Exposure Cohort (SEC) per the *Energy Employees Occupational Illness Compensation Program Act of 2000*, as amended, 42 U.S.C. § 7384 *et seq*. (EEOICPA) and 42 C.F.R . pt. 83, *Procedures for Designating Classes of Employees as Members of the Special Exposure Cohort under the Energy Employees Occupational Illness Compensation Program Act of 2000*.

Petitioner-Requested Class Definition

Petition SEC-00049, qualified on May 1, 2006, requested that NIOSH consider the following class: *Directors and subordinates, Physicists, Chemists, Technicians, Workers that worked at Monsanto Chemical Company in Dayton, Ohio, during the period of 1943 to 1949.*

NIOSH-Proposed Class Definition

This evaluation defines a single class of employees for which NIOSH cannot estimate radiation doses with sufficient accuracy. The NIOSH-proposed class includes: *all Atomic Weapons Employees who were monitored or who should have been monitored for radiation while working at Monsanto Chemical Company Units I, III, or IV in Dayton, Ohio, for a number of work days aggregating at least 250 work days during the period of January 1, 1943 to December 31, 1949, or in combination with the work days within the parameters established for one or more other classes of employees in the SEC.*

Feasibility of Dose Reconstruction

The feasibility determination for the class of employees covered by this evaluation report is governed by the requirements of the Energy Employees Occupational Illness Compensation Program Act of 2000 (EEOICPA) and 42 C.F.R. § 83.13(c)(1). Section 83.13 of the rule states that “Radiation doses can be estimated with sufficient accuracy if NIOSH has established that it has access to sufficient information to estimate the maximum radiation dose for every type of cancer for which radiation doses are reconstructed that could have been incurred in plausible circumstances by any member of the class, or if NIOSH has established that it has access to sufficient information to estimate the radiation doses of members of the class more precisely than an estimate of the maximum radiation dose.”

NIOSH has established herein that it does not have timely access to sufficient information to estimate either the maximum radiation dose incurred by any member of the class or to estimate such radiation doses more precisely than a maximum dose estimate. The sum of information for the period 1943 through 1949 from the available resources is not sufficient to document or estimate the potential maximum internal and external exposure to members of the class under plausible circumstances during the period of radiological operations at Monsanto Chemical Company (MCC).

Health Endangerment Determination

Per EEOICPA and 42 C.F.R. § 83.13(c)(3), a health endangerment determination is required because NIOSH has determined that it does not have sufficient information to estimate dose for the members of the proposed class.

NIOSH did not identify any evidence supplied by the petitioners or from other resources that would establish that the proposed class was exposed to radiation during a discrete incident likely to have involved exceptionally high-level exposures. However, evidence indicates that some workers in the proposed class may have accumulated substantial chronic exposures from the inhalation and ingestion of radionuclides, combined with substantial external exposures to gamma, beta, and neutron radiation. Consequently, NIOSH has determined that there is reasonable likelihood that such radiation doses may have endangered the health of members of the class who were employed for at least 250 aggregated work days either solely under their employment or in combination with work days within the parameters (excluding aggregate work day requirements) established for other classes of employees included in the SEC.

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SEC Petition Evaluation Report for SEC-00049

1.0 Purpose and Scope

This report evaluates the feasibility of reconstructing doses for all employees who worked at Monsanto Chemical Company (MCC) in Dayton, Ohio during the period from 1943 to 1949. It provides information and analyses germane to considering a petition for adding a class of employees to the Congressionally-created Special Exposure Cohort (SEC).

This report does not make any determinations concerning the feasibility of dose reconstruction that necessarily apply to any individual energy employee who might require a dose reconstruction from NIOSH. This report also does not make the final determination as to whether the proposed class will be added to the SEC (see Section 2.0).

This evaluation was conducted in accordance with the requirements of EEOICPA, 42 C.F.R. pt. 83, and the guidance contained in the Office of Compensation Analysis and Support's *Internal Procedures for the Evaluation of Special Exposure Cohort Petitions*, OCAS-PR-004.

2.0 Introduction

Both EEOICPA and 42 C.F.R. pt. 83 require NIOSH to evaluate qualified petitions requesting that the Department of Health and Human Services (HHS) add a class of employees to the SEC. The evaluation is intended to provide a fair, science-based determination of whether it is feasible to estimate with sufficient accuracy the radiation doses of the class of employees through NIOSH dose reconstructions.[1]

42 C.F.R. § 83.13(c)(1) states: *Radiation doses can be estimated with sufficient accuracy if NIOSH has established that it has access to sufficient information to estimate the maximum radiation dose for every type of cancer for which radiation doses are reconstructed, that could have been incurred in plausible circumstances by any member of the class, or if NIOSH has established that it has access to sufficient information to estimate the radiation doses of members of the class more precisely than an estimate of the maximum radiation dose.*

Under 42 C.F.R. § 83.13(c)(3), if it is not feasible to estimate with sufficient accuracy radiation doses for members of the class, NIOSH must also determine whether there is a reasonable likelihood that such radiation doses may have endangered the health of members of the class. The regulation requires NIOSH to assume that any duration of unprotected exposure may have endangered the health of members of a class, when it has been established that the class may have been exposed to radiation during a discrete incident likely to have involved levels of exposure similarly high to those occurring during nuclear criticality incidents. If the occurrence of such an exceptionally high-level exposure has not been established, then NIOSH is required to specify that health was endangered for those workers who were employed for at least 250 aggregated work days within the parameters established for the class or in combination with work days within the parameters established for other SEC classes.

[1] NIOSH dose reconstructions under EEOICPA are performed using the methods promulgated under 42 C.F.R. pt. 82 and the detailed implementation guidelines available at http://www.cdc.gov/niosh/ocas.

NIOSH is required to document its evaluation in a report, and in doing so it utilizes both its own dose reconstruction expertise as well as technical support from Oak Ridge Associated Universities (ORAU). Once completed, NIOSH provides the report to both the petitioners and to the Advisory Board on Radiation and Worker Health (the Board). The Board will consider the NIOSH evaluation report, together with the petition, petitioner(s) comments, and other information the Board considers appropriate, in order to make recommendations to the Secretary of HHS on whether or not to add one or more classes of employees to the SEC. Once NIOSH has received and considered the advice of the Board, the Director of NIOSH will propose a decision on behalf of HHS. The Secretary of HHS will make the final decision, taking into account the NIOSH evaluation, the advice of the Board, and the proposed decision issued by NIOSH. As part of this decision process, petitioners may seek a review of certain types of final decisions issued by the Secretary of HHS.[2]

3.0 Petitioner Requested Class/Basis and NIOSH Proposed Class/Basis

Petition SEC-00049, qualified on May 1, 2006, requested that NIOSH consider the following class: *Directors and subordinates, Physicists, Chemists, Technicians, Workers that worked at Monsanto Chemical Company in Dayton, Ohio during the period of 1943 to 1949.*

The petitioner provided information in support of the petitioner's belief that accurate dose reconstruction over time is not possible because: (1) workers were not monitored through personnel or area monitoring; (2) monitoring records have been lost, falsified, or destroyed; (3) there is inadequate information regarding monitoring, source, source term, or processes from the site; and (4) the petitioner provided a report from a health physicist or other individual with expertise in radiation dose reconstruction which documented the limitations of existing records on radiation exposures as relevant to the petition. NIOSH considered all information included with the submission including SECIS documents 9414 and 9591. In addition, NIOSH reviewed the document titled *Technical Basis Document for the Mound Site* and determined that the petition information was sufficient to qualify SEC-00049 for evaluation.

NIOSH found some support for the petitioner's submission basis during NIOSH's review of available monitoring data for the period of operations at MCC from January 1, 1943 through December 31, 1949. NIOSH concluded that although limited information is available, some employees were not routinely monitored through bioassay or external dosimetry and that there was a potential for unmonitored internal and external exposures based on the production processes that occurred at MCC, including the production of polonium. NIOSH did not find support for the petitioner's submission basis that monitoring records were falsified.

Based on its research, NIOSH modified the petitioner-requested class to define a single class of employees for which NIOSH cannot estimate radiation doses with sufficient accuracy. The class was modified in order to specify MCC units which conducted Manhattan Engineer District operations and to delineate the timeframe for which the operations occurred. The NIOSH-proposed class includes *all Atomic Weapons Employees who were monitored or should have been monitored for radiation while*

[2] See 42 C.F.R. pt. 83 for a full description of the procedures summarized here. Additional internal procedures are available at http://www.cdc.gov/niosh/ocas.

working at Monsanto Chemical Company Units I, III, or IV in Dayton, Ohio for a number of work days aggregating at least 250 work days during the period of January 1, 1943 to December 31, 1949 or in combination with the work days within the parameters established for one or more other classes of employees in the SEC.

4.0 Data Sources Reviewed by NIOSH

NIOSH identified and reviewed data sources to determine the availability of information relevant to determining the feasibility of dose reconstruction for the class of employees proposed for this petition. This included determining the availability of information on personal monitoring, area monitoring, industrial processes, and radiation source materials. The following subsections summarize the data sources identified and reviewed.

4.1 Site Profile Technical Basis Documents (TBDs)

A Site Profile provides specific information derived from the available documentation of historical practices at the specified site. Dose reconstructors can use the Site Profile to evaluate internal and external dosimetry data for monitored and unmonitored workers, and to supplement or substitute for, individual monitoring data. A Site Profile consists of an Introduction and five Technical Basis Documents (TBDs) that provide process history information, information on personal and area monitoring, radiation source descriptions, and references to primary documents relevant to the radiological operations at the site. As MCC was the predecessor site to the Mound Laboratory located in Miamisburg, Ohio, NIOSH included information regarding the Monsanto Chemical Company in the TBDs written for the Mound site. As part of this evaluation, the following TBDs were reviewed:

- *Technical Basis Document for the Mound Site – Introduction*, ORAUT-TKBS-0016-1; Rev. 00; September 9, 2004

- *Technical Basis Document for the Mound Site – Site Description*, ORAUT-TKBS-0016-2; Rev. 00; March 30, 2004

- *Technical Basis Document for the Mound Site – Occupational Medical Dose*, ORAUT-TKBS-0016-3; Rev. 01 PC-2; March 31, 2006

- *Technical Basis Document for the Mound Site – Occupational Environmental Dose*, ORAUT-TKBS-0016-4; Rev. 00; October 6, 2004

- *Technical Basis Document for the Mound Site – Occupational Internal Dose*, ORAUT-TKBS-0016-5; Rev. 00; September 9, 2004

- *Technical Basis Document for the Mound Site – Occupational External Dose*, ORAUT-TKBS-0016-6; Rev. 00; August 11, 2004

4.2 ORAU Technical Information Bulletins (OTIBs) and Procedures

An ORAU Technical Information Bulletin (OTIB) is a general working document that provides guidance for preparing dose reconstructions at particular sites or categories of sites. An ORAU Procedure provides specific requirements and guidance regarding EEOICPA project-level activities, including preparation of dose reconstructions at particular sites or categories of sites. NIOSH reviewed the following OTIBs and procedures describing the program at Monsanto Chemical Company, as well as the methodology for using co-worker data to fill in gaps in monitoring data for some employees and time frames:

- *OTIB: Internal Dosimetry Organ, External Dosimetry Organ, and IREP Model Selection by ICD-9 Code,* ORAUT-OTIB-0005; Rev. 02, December 2, 2005

- *OTIB: Assignment of Missed Neutron Doses Based on Dosimeter Records,* ORAUT-OTIB-00023; Rev. 00; March 7, 2005

- *OTIB: Estimation of Neutron Dose Rates from Alpha-Neutron Reactions in Uranium and Thorium Compounds*, ORAUT-OTIB-0024; Rev. 00; April 7, 2005

- *Procedure: Occupational X-Ray Dose Reconstruction,* ORAU-PROC-0061; July 21, 2006

4.3 Facility Employees and Experts

To obtain additional information, NIOSH conducted telephone interviews with seven former MCC employees who provided some additional information including information regarding early environmental sampling. Information gained from the five interviews was consistent with the Monsanto historical information covered in Mound Technical Basis Documents.

NIOSH's completed interviews have been documented and copies of the interviews have been placed in the Special Exposure Cohort Information System (SECIS) under the category "SEC00049 Non-Submitter Communications:"

- *Non-Submitter Communication - Worker Interview via Telephone*, Interviewers-ORAU Team SEC Health Physicists; July 18, 2006; SECIS Ref ID: Submission 00049, Non-Submitter 71 and 72

- *Non-Submitter Communication - Worker Interview via Telephone*, Interviewers-ORAU Team SEC Health Physicists; July 24, 2006; SECIS Ref ID: Submission 00049, Non-Submitter 73 and 74

- *Non-Submitter Communication - Worker Interview via Telephone*, Interviewers-ORAU Team SEC Health Physicists; July 27, 2006; SECIS Ref ID: Submission 00049, Non-Submitter 76

- *Non-Submitter Communication - Worker Interview via Telephone*, Interviewers-ORAU Team SEC Health Physicists; July 27, 2006; SECIS Ref ID: Submission 00049, Non-Submitter 77

- *Non-Submitter Communication - Worker Interview via Telephone*, Interviewers-ORAU Team SEC Health Physicists; August 7, 2006; SECIS Ref ID: Submission 00049, Non-Submitter 82

- *Non-Submitter Communication - Worker Interview via Telephone*, Interviewers-ORAU Team SEC Health Physicists; September 18, 2006; SECIS Ref ID: Submission 00049, Non-Submitter 88

- *Non-Submitter Communication - Worker Interview via Telephone*, Interviewers-ORAU Team SEC Health Physicists; September 18, 2006; SECIS Ref ID: Submission 00049, Non-Submitter 90

4.4 Previous Dose Reconstructions

NIOSH reviewed its NOCTS dose reconstruction database to locate EEOICPA-related dose reconstructions that might provide information relevant to the petition evaluation. Table 4-1 summarizes the results of this review for the entire period of operations at MCC (1943 through 1949). In addition, Table 4-1 describes data for the two distinct periods of January 1, 1943 through December 31, 1945 and January 1, 1946 through December 31, 1949 (NOCTS data available as of October 24, 2006).

Table 4-1: Number of MCC Claims Submitted Under the Dose Reconstruction Rule

Description	Time Period 01-01-43 to 12-31-45 (Processed lead dioxide)	Time Period 01-01-46 to 12-31-49 (Processed Bismuth Slugs)	Totals 01-01-43 to 12-31-49
Total number of claims submitted for energy employees who meet the proposed class definition criteria	11	50	61
Number of dose reconstructions completed for energy employees who were employed during the years identified in the proposed class definition	3	38	41
Number of claims for which internal dosimetry records were obtained for the identified years in the proposed class definition	4	44	48
Number of claims for which external dosimetry records were obtained for the identified years in the proposed class definition	0	31	31

Note: Only 16 of the claims have just MCC employment. The other 45 claims have MCC and Mound covered employment. Also, the 41 completed dose reconstructions include underestimates that resulted in a greater than 50% probability of compensation and claims that included monitoring data from the mound facility that were used to bound the individual claims.

4.5 NIOSH Site Research Database

The NIOSH Site Research Database was also reviewed to locate documents supporting the evaluation of the proposed class. The documents identified during this review, and evaluated for pertinence to this petition, contained event histories, descriptions of research and development activities, polonium production process descriptions, materials handled, and health physics program activities including polonium bioassay (urinalysis) data from 1943 to 1949 and external dosimetry (film badge) data from 1944 through 1948.

4.6 Polonium Reconstruction (PoRECON) Database

Urine bioassays at MCC were analyzed for polonium-210. The Polonium Reconstruction (PoRecon) database contains radiological bioassay data that was captured from original MCC and Mound Laboratory employee files. The PoRecon database contains individual urine bioassay results dating from 1944 onward. There are 59,000 bioassay results for 1,600 individuals prior to 1950. Results were transcribed from individual employee cards into the database. Original site logbooks were used to verify results. The logbooks did not contain any new information; all data had been previously transcribed into worker records and maintained in worker files in the Mound Record Center. It is unclear whether original logbooks still exist.

4.7 CEDR Database

The Comprehensive Epidemiologic Data Resource (CEDR) is a Department of Energy (DOE) public-use repository of data from occupational and environmental health studies of both workers at DOE facilities and nearby community residents. DOE established an epidemiologic program in the 1960s to monitor the health of its workforce. Later, DOE began an environmental dose reconstruction program to study the potential health risks of releases that spread offsite to communities near DOE facilities. The data collected during these DOE studies are made available in electronic form through CEDR (DOE, 2006). For the purpose of NIOSH's evaluation, its review of CEDR found employee information for MCC and Mound employees beginning in 1943 through 1949. These CEDR data included external ionizing radiation exposure data (X-ray film badges) and polonium urine bioassay results.

4.8 MCC Progress Reports

NIOSH reviewed MCC Progress Reports to gain additional insight into the scope of the MCC program that was involved with monitoring internal exposure to polonium. While no monthly progress reports were available for 1943, monthly progress reports were found for January through November of 1944; July, August, September, October, and December 1945; January through June, August, September, October, and December of 1946; February, August, September, November and December 1947; January, March through June, and September through December 1948; and January, February, and April 1949 (Wolf, July 1945; Silverman, August 1945; Ray, August 1945; Silverman, September 15, 1945; Silverman, September 30, 1945; Ray, October 1945; and Wolf, October 1945). It should be noted that the monthly progress reports became more comprehensive over time.

4.9 Documentation and/or Affidavits Provided by Petitioners

In qualifying and evaluating the petition, NIOSH reviewed the following documents submitted by the petitioners:

- *Submission – Form Standard OMB* (SEC Form B, 2006) and affidavit; SECIS Document ID: 9414 and 9591

- *History of the Dayton Project*, Keith V. Gilbert, Monsanto Research Corporation, A Subsidiary of Monsanto Company, Mound Laboratory, Miamisburg, Ohio, June 1969; SECIS Document ID: 9414

- *The Story of Monsanto - Faith, Hope, and $5,000 – The Trials and Triumphs of the First 50 Years,* Dan J. Forrestal, Simon and Schuster, New York, 1973; SECIS Document ID: 9414

- *Atomic Quest- A Personal Narrative,* Arthur Holly Compton, New York, Oxford University Press, 1956; SECIS Document ID: 9414

- *War Activities of the Central Research Department of the Monsanto Chemical Company*, J.C. Toedtman, January 20, 1945; SECIS Document ID: 9414

- *The Dragon's Tail- Radiation Safety in the Manhattan Project, 1942-1946*, Barton C. Hacker, University of California Press, 1987; SECIS Document ID: 9591

4.10 Documentation from U.S. Army Corps of Engineers Formerly Utilized Remedial Action Program

NIOSH reviewed MCC documents published by the U. S. Army Corps of Engineers Formerly Utilized Sites Remedial Action Program (FUSRAP) that supported the evaluation of the proposed class. The documents identified during this review, and evaluated for pertinence to this petition, were preliminary assessments and site inspection reports pertaining to MCC.

5.0 Radiological Operations Relevant to the Proposed Class

The following subsections summarize both radiological operations at the Monsanto Chemical Company from January 1943 to December 1949 and the information available to NIOSH to characterize particular processes and radioactive source materials. From available sources, NIOSH has gathered process and source descriptions, information regarding the identity and quantities of radionuclides of concern, and information describing both the processes through which radiation exposures may have occurred and the physical environment in which they may have occurred. The information included within this evaluation report is meant only to be a summary of the available information.

5.1 Monsanto Chemical Company Plant and Process Descriptions

In the summer of 1942, the United States Army organized the Manhattan Engineer District (MED) for the purpose of developing an atomic bomb. As a source of neutrons for the initiators of the nuclear explosion, polonium was vital to MED activities. Significant quantities of polonium were required to construct the essential "trigger" for the bomb.

In 1943, at the request of the MED, Charles Allen Thomas, Director of MCC's Central Research Division, agreed to head up research into the chemistry and metallurgy of polonium-210: beginning a critical part of the MED, called the Dayton Project (operated by MCC). The Dayton Project's ultimate objective was to fabricate the bomb initiators and supply them on a timely basis to a designated weapons assembly site. Prior to MCC's involvement in the Dayton Project, no visible or measurable quantities of the pure element polonium-210 had ever been produced. Production of that pure metal required pioneering research, experimentation, and development of innovative production processes (Moyer, 1956).

Although manufacturing focused upon polonium-beryllium sources, polonium production research included experimenting with the chemistry of polonium and other elements that might serve as neutron sources. In addition, the Dayton Project experimented with making both solid and liquid polonium sources of varying types.

Naturally occurring sources of polonium, such as lead-containing wastes from uranium, vanadium, and radium refining operations, were first used (November 1943 through May 1945) at MCC as the raw material from which polonium was purified to prepare neutron and alpha sources. However, a subsequent investigation of available sources of naturally occurring polonium-bearing ores found that (1) polonium could not be recovered from these sources without processing prohibitively large quantities of raw material; (2) in commercial refining methods, polonium was not concentrated in any particular step of the process, but could be found in several of the solutions or residues, making processing of more than one waste fraction necessary; and (3) the supply of refinery residues available for polonium processing was uncertain and depended upon operating schedules of industries primarily concerned with the production of uranium and radium (Moyer, 1956).

In 1943, researchers at MCC believed that the most promising method for the production of polonium would be irradiated bismuth. However, since the irradiation process had not been developed to the point of production, they were compelled to use natural sources of polonium. The researchers decided to separate polonium from the radioactive lead residues generated at the Canadian radium refinery in Port Hope. The production schedule at Port Hope called for 30 curies of radium per month; hence, this appeared to be an excellent potential source of polonium (Moyer, 1956).

5.1.1 Polonium from Uranium Ore Residues

MCC received the first shipment of approximately 3.5 tons of lead dioxide from Port Hope in November 1943. Altogether, nearly 37 tons of lead dioxide were received and processed until May 1945, when operations using the lead process were discontinued. The total quantity of polonium obtained from this source was approximately 40 curies (Moyer, 1956).

MCC then investigated three methods for producing polonium from radioactive lead residues: (1) the lead chloride method (Dillon process); (2) a dry thermal volatilization method (Kiln process); and (3) a wet chemical method (Chemical process).

Patent literature presented the Dillon process as a workable method that could be put into immediate operation. Early in 1944, after preliminary laboratory experiments indicated that the process was indeed usable, MCC began comparatively small-scale operations. By March 1, 1944, MCC had processed three tons of radioactive lead with approximately 2.5 curies of polonium deposited on nickel and copper plates. This represented an estimated efficiency of approximately 80 percent in the removal of polonium from the lead dioxide. However, this plating of polonium on copper and nickel strips by no means completed the process of isolating the element; at this stage the 0.5 mg of polonium was spread over 461 metal plates with a total surface area approximating 1,700 square feet. Attempts to concentrate and collect the polonium from the metal surfaces using distillation were only partially successful. By March 1944, with other production processes showing greater promise, the Dillon process was abandoned (Moyer, 1956).

Early researchers recognized the volatility of polonium. The alpha and beta activities from radioactive lead could be separated by heating the active deposits on platinum foils to 1000° C. Therefore, it appeared probable that polonium might be separated from lead dioxide by direct heating. Preliminary laboratory experiments found that the activity could be removed from lead dioxide by heating that material to 600 to 700° C in a stream of carbon dioxide.

MCC then developed a procedure that used the Kiln process to distill polonium from metal foils and collect the volatilized element on cooled aluminum strips. MCC first built and tested two stainless-steel kilns; the first kiln was an agitator type with a capacity of 3 to 8 pounds and the second was a rotary type with a capacity of about 15 pounds, built with dimensions proportional to a proposed production model.

In the first runs using the agitator-type kiln, MCC used lead dioxide, but the charge sintered at 700° C, resulting in slag that had to be chiseled out of the kiln. Because the slag prevented stirring the charge and because polonium volatilization was incomplete at 700° C, MCC replaced lead dioxide with lead orthophosphate.

All subsequent runs in the kilns were made with lead orthophosphate, which was prepared by treating lead dioxide directly with phosphoric acid. Pilot-plant runs in the small kiln found that it was necessary to heat the lead phosphate in a current of carbon dioxide for at least four hours at 750 °C. MCC tested various types of condensers for collecting the polonium, the most successful being a water-cooled brass finger containing a Pyrex glass-wool filter. However, the results were inconsistent, in part due to the difficulties in screening out inactive dust particles and in preventing the fine dust from carrying the active material through the filters. Several runs were made with the second kiln, which operated quite well mechanically, but generated discouraging volatilization and collection data. In addition, dusting was greater than anticipated and resulted in machinery and personnel becoming grossly contaminated. In the meantime, a chemical process had been developed which appeared sufficiently promising; thus work with the kilns was discontinued (Moyer, 1956).

Before the Irradiated-Bismuth process was developed, chemical treatment of the Port Hope lead dioxide had proved to be the most successful method of obtaining polonium. The first step in the

Chemical process was to convert the lead dioxide to lead nitrate by treating the lead dioxide with concentrated nitric acid and 27 percent hydrogen peroxide.

Next, prior to filtering the insoluble portion of the lead dioxide, lead carbonate was added to reduce acidity to a pH level of approximately 4.0. The addition of lead carbonate caused a number of undesirable elements, including iron and aluminum, to precipitate out. The insoluble siliceous residue separated by filtration was a complex mixture which carried with it the polonium that had grown in the lead dioxide prior to treatment. Recovering the polonium from radioactive lead residues involved two approaches: (1) recovering the polonium initially present in the lead dioxide and (2) periodic milking of the lead nitrate solution obtained by dissolving the lead dioxide.

Radioisotopes present in lead dioxide obtained from ore processing would include those from the entire uranium-238 decay chain, with the exception of the short-lived radium daughters. The Chemical process produced approximately 40 curies of polonium, most of which came from recovering the polonium initially present in the lead dioxide (the first operation). Although a total of 35 tons of lead dioxide was treated to prepare the nitrate solutions, milking of the lead nitrate solutions (the second operation) did not advance beyond the pilot-plant stage.

5.1.2 Polonium from Irradiated Bismuth Slugs

The conversion of bismuth-209 to bismuth-210 had been reported in 1935, and because bismuth decays rather rapidly to polonium-210, bismuth, which had been subjected to neutron bombardment, appeared to be a more suitable source of polonium than naturally occurring ores. Relatively pure bismuth was available in commercial quantities and separation of polonium from a raw material containing impurities of the order of a few parts per million would be less difficult than separation from refinery wastes containing larger amounts of impurities. As methods for irradiating bismuth by neutron bombardment and methods for separating polonium from irradiated bismuth were developed, other production methods involving lead dioxide were abandoned.

MCC received its first irradiated bismuth from the Clinton reactor located in east Tennessee. That bismuth contained between 0.032 and 0.083 curies of polonium per kilogram of bismuth, resulting in one ton of the first irradiated bismuth containing 29 to 75 curies of polonium. This was a vast increase over the yield of 1 to 3 curies per ton from the Port Hope lead dioxide (Moyer, 1956). Thus, the Bismuth process proved the most successful at producing polonium.

5.1.3 Other Radiological Work at MCC

Although MCC was principally involved with the separation and purification of polonium-210, it also performed other radiological work involving research and development of calorimetry and other instruments to measure small quantities of alpha-emitting radionuclides. MCC also assisted in mechanical development of micro-beam balances and electronic equipment, as well as limited biological research on the toxic effects of polonium (Unit III History Report). MCC developed a process for manufacturing polonium-beryllium sources by electroplating the polonium onto an inert substrate, then chemically or electrochemically reacting beryllium with the plated polonium to form a stable solid source. MCC used similar processes to manufacture americium-beryllium sources and plutonium-beryllium sources. Neutron and alpha particle sources, powered by polonium-210, were manufactured for sale to government and research organizations.

Table 5-1 is a chronological summary of the events that took place during the early years of MCC.

Table 5-1: Chronology of Significant MCC Programs and Events	
Year	**Activity**
1943	Planning begins for Dayton facilities Lead dioxide is received in November
October 1944	Polonium operations begin at Unit III
1946	Mound Laboratory planning started
1949	Polonium operations moved from MCC to Mound Laboratory; conclusion of Manhattan Engineer District research/development and production activities at MCC

The principal contaminant at MCC was polonium-210 (Moyer, 1956). Other contaminants included bismuth, cobalt, nickel, beryllium, thorium, uranium (and uranium progeny), radium, and lead-210. In addition, tellurium was a common contaminant in the irradiated bismuth slugs and cobalt was a common impurity in the aluminum cans used to jacket the bismuth slugs. Nickel and beryllium originated from the polonium source production and initiator production programs. Finally, various MCC research projects involved radionuclides that included relatively small quantities of carbon-14 and hydrogen-3 (ORAUT-TKBS-00016-4).

Irradiated bismuth slugs arrived at MCC protected in aluminum cans. MCC developed wet chemistry processes to remove the bismuth slugs from the aluminum cans through dissolution. That hydrolysis method produced waste sludge containing significant quantities of radioactive materials. Polonium-210 was the primary nuclide of concern. Other nuclides of possible concern that were contained in the sludge included: antimony-124; bismuth-210; cesium-137; cobalt-60; iron-55 and -59; lead-209 and -210; mercury-203; polonium-208 and -209; selenium-75; strontium-90; tellurium-121 and-132; tin-121; and zinc-65. Several of these radionuclides have relatively short half lives (17 days or less), and the time from initial irradiation of the bismuth slugs at Hanford to the time of processing at MCC would have allowed for significant decay.

5.2 Monsanto Chemical Company Unit Descriptions

Under the Dayton Project, the MCC site encompassed multiple locations within the Dayton, Ohio, area. These locations were known as units, with each unit having multiple buildings. Table 5-2 lists the MCC units and addresses.

Table 5-2: MCC Locations and Descriptions	
Location	**Description**
Unit I	Monsanto Central Research Department-1515 Nicholas Road, Dayton, Ohio
Unit II	Monsanto rocket propellant laboratory off Betty Lane, adjacent to present-day St. Henry's Church next to Dayton Mall
Unit III	Bonebrake Theological Seminary, 1601 W. First Street, Dayton, Ohio
Unit IV	Runnymede Playhouse, Dixon Avenue and Runnymede Road in Oakwood, Ohio
Warehouse	Warehouse at 3rd and Sears Street, Dayton, Ohio
Marion	Duplicate production facility in Marion, Ohio
Mound	Mound Laboratory, Miamisburg, Ohio (also called Unit V)

5.2.1 Monsanto Chemical Company Unit I

Monsanto started its preliminary organization of the Dayton Project in September 1943 at the company's Central Research Department located on Nicholas Road in Dayton, Ohio. When the project expanded to other locations during World War II, the original Nicholas Road location became known as Unit I. Spectrographic and X-ray work for the project remained at this location until Mound Laboratory was completed in 1949 (Moyer 1956). Polonium was not produced at this location.

5.2.2 Monsanto Chemical Company Unit II

During the early years of the Dayton Project, Monsanto also independently operated a separate facility, known as Unit II, to produce rocket propellants. Explosives produced at Unit II included ammonium picrate and ammonium nitrate. However, no radioactive materials were handled at this location. Monsanto Chemical Company phased out the rocket propellant operation in the fall of 1945 (Meyer 1994).

5.2.3 Monsanto Chemical Company Unit III

Early in July 1943, it became apparent that the Nicholas Road (Unit I) location was not sufficient to house polonium production operations. Due to time and material limitations and rental space being at a premium, construction of a new research laboratory was impossible. As a result, MCC leased a three-and-a-half story building at 1601 West First Street in Dayton, Ohio. This building, which was built in 1879, was used to house the Bonebrake Theological Seminary and later became known as Unit III.

Unit III was occupied in October 1943. A hasty but extensive renovation was necessary to prepare the building for service as a chemical research laboratory. A steel Quonset hut and several small block buildings were erected to increase the usable space for machine operations, a powerhouse, and a cafeteria. Eventually, Unit III consisted of twenty buildings (Moyer, 1956). Dayton Project activities began in Unit III in October 1944 and Unit III supported research into manufacturing of neutron sources. In addition, pilot plant investigations into waste disposal by incineration began in February 1948, with the first pilot plant operating for about six weeks (Unit III History Report). The principal radioisotope at Unit III was polonium-210. In April 1948, a successful polonium-boron trifluoride gaseous neutron source was created there.

Operations at Unit III ceased in 1948, with polonium operations being transferred from MCC to Mound Laboratory in1949 (ORAUT-TKBS-0016-2). This transition of operations appears to have occurred incrementally over months. The buildings at Mound Laboratory were occupied as they were completed, the first in May 1948. At Mound Laboratory, processing polonium to produce neutron sources and alpha sources began in February 1949 (Moyer 1956).

The cleanup target for Unit III was 5,000 disintegrations per minute per 100 square centimeters (d/min/100 cm^2) which corresponds with about 2.3 nCi/100 cm^2 (Unit III History Report). All Unit III buildings exhibited levels of radioactivity low enough to permit decontamination. In 1950, the building was decontaminated and returned to its owner, the Dayton Board of Education. This subsequent period of decontamination work was performed by Mound Laboratory personnel under Mound Laboratory management and monitoring; therefore, the decontamination work is not covered under this petition evaluation. Other buildings constructed on the site for the powerhouse and machine shops were demolished. Radiological waste was packaged and shipped to Oak Ridge, Tennessee, for burial.

5.2.4 Monsanto Chemical Company Unit IV

From its inception, the Dayton Project expanded in less than one year to encompass 200 people. With the growth of both the polonium production project and the staff, it became apparent that additional space was needed. In February 1944, the Army Corps of Engineers leased the Runnymede Playhouse in Oakwood, Ohio, (at the southern boundary of Dayton) for use by MCC. The Runnymede Playhouse was a relatively large, private recreational building constructed in 1927 by the Talbott family for private activities. It included several greenhouses, an indoor tennis court, a squash court, lounges, and an outdoor swimming pool. Part of the structure had a corrugated glass roof (Gilbert 1969). This location was designated as Unit IV.

Unit IV was used to manufacture and calibrate neutron sources. The principal radioisotope at Unit IV was polonium-210. Unit IV wastes were packaged and sent to Oak Ridge, Tennessee, for burial. Radiological surveys found that the interior of the playhouse was highly contaminated. In order to reduce costs and minimize radiological exposure to personnel, the playhouse was dismantled rather than restored to its original condition. Many of the interior rooms, partitions, ceilings, walls, floors, and mechanical and electrical equipment at Unit IV had to be removed before the building was demolished. Since Unit IV was to undergo demolition, a target cleanup of 50,000 d/min was used (a factor 10 times higher than the limit used at Unit III) (MLM-461). Unit IV was demolished in 1950. This subsequent period of demolition work was performed by Mound Laboratory personnel under Mound Laboratory management and monitoring; therefore, the demolition work is not covered under this petition evaluation. By spring 1950, all Unit IV structures, services, and utilities had been removed to a depth of seven feet, packaged, and shipped to Oak Ridge for burial. Clean fill dirt replaced the excavated soil and the remediated property was returned to the Talbott family estate.

5.2.5 Monsanto Chemical Company Warehouse

To meet continuing expansion needs, in 1946 MCC leased several floors in a large warehouse in Dayton, Ohio, at Third and Sears Streets. This warehouse was originally used to store non-contaminated materials, but because it was radiologically clean and posed no risk of cross-contamination, it was used as a space to analyze trace quantities of polonium-210 from environmental monitoring samples, bioassay samples from personnel, and to conduct animal studies on the effects of polonium exposure (Meyer, 1992). Warehouse samples and waste materials, including plated copper discs from the polonium analysis, were discarded with the regular warehouse trash.

At this time the warehouse is not recognized as a Monsanto Chemical Company covered facility. Therefore, this facility will not be addressed further in this evaluation.

5.2.6 Marion

A standby facility, which was a duplicate of the Mound T-Building, was built in Marion, Ohio. The T-Building was located in the Mound Laboratory and was the primary polonium production building. Although the Marion facility duplicated the T-Building at Mound, it never received radioactive material. Later, process equipment was dismantled and the facility was turned over to the General Services Administration (GSA).

5.2.7 Mound Laboratory (Also Known as Unit V)

As early as 1946, it was evident that a large-scale polonium production facility was needed. The site selected for the permanent Mound Laboratory (named Unit V) facility was located on a hill 878-feet above sea level and approximately 200-feet above the Miami River in Miamisburg, Ohio. In May 1948, personnel began to occupy the Mound facility. Originally, the Mound facility contained fourteen buildings with 360,000 square feet of space. Beginning in February 1949, Mound Laboratory began processing polonium.

Mound Laboratory became the first permanent facility to be designed and constructed by the U.S. Atomic Energy Commission (AEC), and as such, it was not considered part of the Dayton Project. In addition, the Department of Energy Worker Advocacy listing of sites presents Mound Laboratory as a separate site and does not include it as one of the original MCC facilities.

5.2.8 Summary of Key Monsanto Chemical Company Facilities

Table 5-3 summarizes the key processes as well as the buildings and dates of operation.

Table 5-3: Key MCC Facilities, Operations, and Dates of Operation

Location	Facilities	Dates
Unit 1	**Monsanto Central Research Department (Nicholas Road, Dayton, OH):** Administrative functions; Spectrographic and X-ray work	1943-1949
Unit II	**Rocket Propellant Laboratory (Betty Lane, Dayton, OH):** Research and Production of rocket fuels—No radionuclides onsite	1943-1949

Table 5-3: Key MCC Facilities, Operations, and Dates of Operation		
Location	**Facilities**	**Dates**
Unit III	**Bonebrake Theological Seminary (W. First St., Dayton, OH):** Research and Development, production of polonium-beryllium and other neutron sources	1944-1949
Unit IV	**Runnymede Playhouse (Dixon Ave. & Runnymede Rd., Oakwood, OH):** Polonium production and calibration of neutron sources using polonium	1944-1949
Marion	**Marion Facility (Marion, OH):** Constructed as a duplicate of the T Building at Mound—No radionuclides onsite	1946-1954

5.3 Radiological Exposure Sources from MCC Operations

The potential sources of radiological exposure at MCC were from laboratory research operations that supported the development of polonium extraction processes and the production of polonium neutron sources. Supporting documentation also indicates that research activities, and therefore potential exposures, were performed at MCC using thorium and radium (Author unknown, 1945; Author unknown, date unknown) and that there was a potential for exposures to uranium (and associated uranium progeny) which would have existed as a contaminant or byproduct in the early extraction of polonium from ores (Moyer, 1956).

During the initial stages of the Dayton Project, MCC separated polonium-210 from naturally occurring materials to create polonium-beryllium source neutron generators for atomic bomb initiators. By 1944, the decision was made to transform bismuth-209 into polonium-210 via neutron bombardment (ORAUT-TKBS-0016-6).

The bismuth process started at MCC in 1945. Initially, 58-pound bismuth bricks that had been irradiated in the Clinton reactor at Oak Ridge, Tennessee were shipped to MCC. Eventually, MCC obtained irradiated bismuth slugs from Hanford. Hanford manufactured the irradiated bismuth slugs that were later shipped to MCC, in part by casting the bismuth into slugs and inserting each slug into an aluminum can that was welded shut. The canned bismuth was then irradiated, packaged in lead casks, and shipped to MCC for use in producing polonium. Post-1945, irradiated bismuth became the principal source of polonium (Wolf, August 1945).

It is important to note that the lead dioxide, from which polonium was extracted, contained impurities including iron, silicon, tellurium, selenium, silver, and uranium (which is assumed to include uranium progeny) (Moyer, 1956). In the polonium extraction process associated with the bismuth slugs, both the bismuth and aluminum cans contained impurities, including iron, silicon, cobalt, lead, tin, zinc, silver, chromium, vanadium, and gallium. During irradiation, these impurities were neutron-activated and produced gamma-emitting isotopes, creating additional internal and external radiation hazards. Furthermore, internal correspondence indicates that laboratory research was also performed with thorium and radium at MCC (Author unknown, 1945; Author unknown, date unknown).

5.3.1 Alpha Particle Emissions

Alpha particle emissions from radioactive materials handled at MCC presented the greatest potential internal deposition hazard; via inhalation and ingestion (alpha particles do not present an external exposure hazard). Initially, the principal alpha-emitting radioactive materials associated with MCC were various uranium residues (lead oxides). Naturally occurring sources of polonium, such as lead-containing wastes from uranium, vanadium, and radium refining operations, were first used at MCC as raw material from which polonium was purified. Starting in 1945, irradiated bismuth was the principal material used as the feedstock for polonium production.

Polonium-210 has a relatively short half-life of 138.39 days and emits alpha particles with energies of 5.31 MeV. A milligram of polonium-210 emits as many alpha particles as 5 grams of radium. A great deal of energy is released by its decay; a half gram of polonium quickly reaches a temperature above 750º K (890° F, 477° C). Polonium is a volatile metal, with 50% being vaporized in air after 45 hours at 328º K (131° F, 55° C) (Polonium). Therefore, the inhalation route is considered to have the greatest potential for causing exposure.

5.3.2 Beta Radiation Fields

Initially part of the Manhattan Project, the Dayton facility separated polonium-210 from naturally occurring materials to produce polonium-beryllium source neutron generators for atomic bomb initiators. By 1944, the decision was made to transmute bismuth-209 into polonium-210 via neutron bombardment. That reaction can be stated as: 83 209Bi + η→ 83 210Bi → 84 210Po + β-. The beta radiation from the irradiated slugs was so intense that they could not be handled without lead gloves and tongs (ORAUT-TKBS-0016-6).

Polonium impurities produced a number of activation products that were beta emitters. Silver-112 was a particular problem with beta particles of 3.94 MeV and caused the irradiated ingots to generate high dose rates. Other beta-emitting radionuclides of concern were antimony-124 (2.31 MeV), iron-59 (1.57 MeV), cobalt-60 (1.48 MeV), cesium-137 (1.176 MeV), bismuth-210 (1.160 MeV), tin-121 (0.42 MeV), zinc-65 (0.327 MeV), and mercury-203 (0.214 MeV).

5.3.3 Neutron Exposures

Neutron exposure could have resulted from polonium research and development activities and from polonium-beryllium source production that occurred in Units III and IV during the time period covered by this SEC evaluation report. Details regarding the research and experiments are not available and NIOSH has located only limited information regarding neutron monitoring data for the pertinent timeframe (1943-1949).

The *Neutron Source Progress Report* indicates that Mound shipped a polonium-210-beryllium neutron source to Brookhaven National Laboratory on October 25, 1948. The opening paragraph of the *Neutron Source Progress Report* references a report titled *Work Done in Preparing Neutron Sources from Polonium and Beryllium between September 5, 1945 and May 25, 1947* and implies that polonium-beryllium sources were manufactured at one or more of the Mound precursor sites, such as MCC, between September 5, 1945, and May 25, 1947 (MLM-220).

The energy spectrum for polonium-beryllium neutron sources has an average energy of about 4.5 MeV (Bigler, 1969-1979). Approximately 75% of the neutrons produced at MCC would have had energies between 2 – 20 MeV, and approximately 25% of the neutrons would have had energies between 100 – 2,000 keV (ORAUT-TKBS-0016-6).

5.3.4 Photon Exposures

At MCC, exposure to photons were associated with research and development, polonium production, and the manufacturing of radioactive sources that occurred primarily in Units III and IV. Approximately 75% of the photon energies were greater than 250 keV, and roughly 25% of the photon exposure potential would have been derived from photons between 30 and 250 keV (ORAUT-TKBS-0016-6).

5.3.5 Medical X-Ray Exposures

Diagnostic X-ray procedures also contributed to the occupational radiation exposure of Monsanto workers. However, the dose from such exposures was not measured, considered, or included as part of the overall occupational exposure of the employee. Beginning in 1946, MCC employees received posterior–anterior (PA) chest X-rays as a baseline at hiring, at specified intervals thereafter, and at termination. However, the technique factors such as total filtration, half-value layer, current, voltage, and exposure time that were used during the chest X-rays are unknown. In addition, there are no site-specific records to indicate the use of photofluorography at MCC; therefore, this analysis assumes that photofluorography did not occur at MCC.

5.4 Health Physics Program at MCC

The health physics program at MCC for the 1943 through 1949 timeframe was administered by the MCC Medical Section and was based on programs being implemented at other laboratories and research facilities during that time. The program recognized the existence of radiological hazards at MCC, including potential exposures to alpha, beta, photons, and neutron radiations. It considered modes of exposure (*i.e.*, ingestion, inhalation, and external exposure modes) and took preventive actions to minimize personnel exposures. The MCC health physics program included radiological data collection, analysis, and reporting by physicists and medical personnel.

The first set of “General Health and Safety Rules” for the Dayton Project was compiled in December 1943 by L. B. Silverman of the MCC Health and Safety Group (Silverman, 1962). Early in 1944, MCC created a bioassay method to monitor personnel working with polonium. By April 8, 1944 (MCW, 1944), discussions were being held at MCC to evaluate the procedures in place to monitor individuals for exposure to polonium. In part, these discussions resulted in establishment of “Tolerance Levels” for the maximum daily radiation dose that an individual could receive during operations at MCC. It is important to note that these tolerance levels were based on non-stochastic health effects. The initial whole-body penetrating tolerance level was 0.1 R/8-hours and 0.7 R/week. The beta tolerance level was 0.5 R/8-hours and 3.5 R/week. Initially, data from urine bioassays, personnel contamination levels, and area contamination levels were used to compare exposures to the tolerance levels. When tolerance levels were exceeded, protective actions were to be taken, such as removing a person from work on the task where the exposure occurred.

Personnel monitoring, using dental X-ray film badges, was used to measure exposure to beta and gamma radiation. Documentation of external exposure monitoring using dental X-ray film badges is available from as early as March 1944 (Ferry, 1944). Individuals were assigned badges on a monthly basis. The results were presented as "Results of Film Density Measurements" and were given as Roentgens per week and times tolerance. Communications between the laboratory analyzing the badges and the Medical Department indicate that an effort was made to continually improve the technology and the implementation of the X-ray film badge program. For example, correspondence from April 1944 recommends introducing a control badge into the program (Ferry, 1944).

The MCC Health Physics Program was progressive in attempting to reduce personnel exposures. For example, in the earliest years of polonium operations (1944 through 1946), the maximum permissible body burden was 2.0 uCi. In 1947, at the urging of national health physics professionals, such as Dr. Karl Z. Morgan at Oak Ridge, Tennessee, the maximum permissible body burden for polonium was reduced by a factor of 10, from 2.0 uCi to 0.2 uCi. Consequently, the urine count limit in a 24-hour urine sample was also reduced from an early accepted value of 3000 d/m to only 500 d/m (Meyer, 1992 and Naimark, 1949). As stated previously, it is important to note that these earlier tolerance levels were based on non-stochastic effects.

Written communications, such as MCC Unit Progress Reports and MCC Monthly Health Information Reports, document the evolution of assay techniques, lessons learned, and other MCC programmatic improvements that occurred over time and as employees gained experience (Wolf, August 1945; Wolf, December 1945). The periodic reports include brief descriptions of accidental spills of radioactive materials, personnel contamination events, and other personnel exposures. There is documentation regarding actions taken to minimize contamination. For example, decontamination operations and recommendations such as minimizing exposure to contaminated gloves were employed at MCC.

6.0 Summary of Available Monitoring Data for the Proposed Class

Radioactive materials were processed and produced at MCC from November 1943 through 1949. Some personal and area monitoring data for the proposed class of MCC employees evaluated in this report are available for 1944 through 1949. The results of NIOSH data reviews are provided in the following subsections.

6.1 Monsanto Chemical Company Internal Monitoring Data

While the primary area of health physics internal monitoring activity was the polonium urine bioassay monitoring program, other internal monitoring data such as blood test results and air samples were also periodically collected and analyzed.

According to the MCC Unit III Progress Report for June 16-30, 1944, a preliminary schedule for weekly urine bioassay monitoring had been proposed. Beginning in 1944, urine bioassay monitoring was conducted at MCC using routinely collected urine samples from workers (Meyer, 1992). NIOSH's review of the radiological exposure data contained in the PoRecon database located urine bioassay records for polonium exposures occurring between 1944 and 1949. Although there is no way to determine how many workers were employed exclusively at Mound or MCC, there are 1,600 individuals noted in the PoRecon database for the time period between 1944 and 1949. PoRecon holds results for 59,000 polonium urine bioassays for the years relative to this SEC petition. In addition to reviewing the PoRecon database, NIOSH reviewed the urine bioassay results which are also contained in the CEDR database.

In vitro urine data comprises the primary source of information that would be used to support dose reconstruction. Table 6-1 summarizes the MCC urine bioassay program, noting the analytical method, radionuclide action level in counts per minute for a urine sample, workers who were monitored, and frequency of monitoring.

Table 6-1: Urine Bioassay Program and Action Level

Bioassay Program	Date Implemented	Action Level[1]	Monitored Workers	Frequency
***In vitro* monitoring**				
Polonium-210 (Postum) recovery Analytical Method Used : spontaneous electrodeposition from raw urine, low background proportional counting	January 1945 January 1946 April 1946	125 cpm/50 ml 50 cpm/50 ml 24 cpm/50 ml	Operations personnel	Weekly spots Weekly 24 hour

Note:
[1] Observed counts per minute for 50 ml or 24-hour samples that result in a worker dose of 300 mrem wk^{-1} to the target organ

MCC placed a substantial emphasis on blood sampling, focusing on the impact of radiological exposure on an individual's white blood cell count (Silberstein, August 1945). Blood samples were collected on a monthly basis from technical personnel and janitorial staff. If an acute exposure occurred, the Medical Department recommended that the blood count be taken as soon as possible, and again within 48-hours after the exposure, followed by weekly blood counts (MCW, 1944). Blood sampling continued through 1949.

There are some additional data indicating that radiological analysis of blood was also performed on a limited basis. Gross alpha results for blood sample analysis are given in cpm/ml (Silberstein, 1945). NIOSH has not located any documentation of quality assurance parameters associated with the blood sample data.

While inhalation intakes would have occurred beginning with polonium-210 production at Units III and IV, breathing zone air sampling was not initiated until after 1947. However, there is some ambient air monitoring data available for Units III and IV from as early as mid-1945.

6.2 Monsanto Chemical Company External Monitoring Data

NIOSH located external monitoring data that include film badge records and some historical information regarding monitoring for neutrons.

6.2.1 External Photon Monitoring Data

In February 1944, MCC began a personnel monitoring program to measure penetrating photon radiation. The monitoring program included employees involved in the process of extracting polonium-210 from irradiated bismuth slugs. Table 6-2 lists the history of MCC film badge dosimetry. As noted in Table 6-3, badges containing X-ray film were exchanged weekly (Ferry, 1944). Table 6-4 summarizes the historical exposure standards to which the MCC health physicists compared the external photon monitoring results.

Table 6-2: Dosimeter Assignment Policies

Date	Photon Dosimetry
February 1944	Finger ring (beta) and whole-body film badges provided to some workers. Weekly limits and reports.
August 1946	Wrist film badges provided to production employees. No individual employee data recoverable until January 17, 1947.

Note:
One week is defined as a 40-hour work week in a 7-day period ending Friday

Table 6-3: Dosimeter Exchange Frequency

Period	Dosimeter Type	Dosimeter Holder	Exchange Frequency	Comments
1944 through 1946	Dental Film	Ring and Brass Badge	Weekly	Not all workers were monitored
August 1946 through January 1949	Kodak Dental Films	Unknown	Weekly	Films worn on wrist only
February 1949 through December 1949 [1]	DuPont D552	Oak Ridge/Steel	Weekly	All radiation workers

Note:
[1] Overlap with individuals working at Mound

Table 6-4: Historic Dose Limit Standards

Period	Radiation Type	Dose Limits
December 1943 through 1946	Photon	100 mrem/d, 26 rem/yr γ; 500 mrem/d-3.5 rem/wk ß, 182 rem/yr ß [1]
August 1946 through 1949	Photon	300 mrem/40-hr wk; 15 rem/yr

Source: *Film Badge Data for 1944* (Ferry, 1944)
Note:
[1] The doses from finger ring (beta) and body badges (gamma) are imputed (52 X weekly limits). The records appear to indicate that only weekly dose limits were imposed.

Pocket ionization chambers were also used at MCC, but data from these were not recorded until after polonium operations began in February 1949 at Mound (ORAUT-TKBS-0016-5). Pocket ionization chambers are sensitive only to photon radiations and because of their typical photon energy dependence, have varying response to photons with energies below about 100 keV. Workers were issued two pocket ionization chambers along with their film badge.

Whole body film badge data beginning February 22, 1944 is available. Whole body film badges were issued to MCC personnel from the University of Rochester office of the Manhattan Engineer District. The results during the first nine months (206 badges) were reported as gamma roentgens per eight hour day. Most non-detectable results were reported as "0," but some badges were reported as (<) values. Following that period, badges had results reported as gamma average R/week.

6.2.2 External Beta Monitoring Data

Beginning February 22, 1944, individual extremity beta doses (using finger ring badges) and whole-body photon doses (using film badges) were reported by worker name (Ferry, 1944). Exposure limits were established per work day and work week. Prior to 1944, there is no indication that a continuous record of individual doses existed, only that weekly reports were issued.

While individual exposure data were reported in February 1944, it should be noted that there is incomplete individual dosimetry for February 1944 through June 1944 and for May 1946. In the 1946 dosimetry, worker names were numerically coded in the record. At some point subsequently, the code key was lost for both beta and photon exposures. As a consequence, individual dose records before January 17, 1947, when exposures were again logged by worker name, are not available.

6.2.3 External Neutron Monitoring Data

Polonium-beryllium sources were manufactured at one or more of the MCC units between September 5, 1945 and May 25, 1947 (MLM-220). In December 1945, a request was made for four neutron-measuring film badges in addition to the five slow neutron pocket electrometers that were noted as being on order (Wolf, December 1945). However, no record of neutron monitoring is available for the time period.

Another documented reference to neutron dose monitoring is in a March 26, 1946 letter from J. Russell Hayes to Dr. B. S. Wolf (Hayes, 1946). Hayes states that neutron monitoring experiments had been carried out during the two previous months but recommended that Hayes' lab continue to read the Dayton neutron monitoring film. It was not until 1947 that researchers realized they had been exposed to neutrons from alpha-n reactions with their multi-curie batches of polonium.

In August 1948, MCC set a tolerance level for neutrons at 0.1 R/8 hour (Bradley, 1948). However, no neutron dosimetry records have yet been found for periods before September 1949. Thus, neutron doses before that date are considered to be unmonitored. Neutron dose monitoring began on August 17, 1949, but the first report of neutron doses was in the September 1949 Monthly Health Information Report, dated October 18, 1949. Neutrons were limited to 200 n/cm2-sec, and there is no documentation of the neutron spectra. The record on historic dose limit standards is ambiguous, and as a consequence, the neutron exposure record must be inferred.

Details regarding the various analyses and the associated minimum detectable activities are presented in the *Technical Basis Document for the Mound-Occupational External Dose* (ORAU-TKBS-0016-6).

6.3 Monsanto Chemical Company Air Sampling Data

Available MCC progress reports indicate that some indoor air sampling was being conducted as early as June 1944 and continued through 1949 (Tybout, 1944). Early sampling was performed using an electrostatic precipitator and measurements were made with a Dershem electrometer. Gross alpha results of air sample analyses are discussed in terms of dis/min/cubic meter of air. Although progress reports discuss sampling being conducted at MCC, with the exception of occasional results, sampling data are unavailable prior to 1947.

MCC established a tolerance level of 2400 dis/min/m3 for air, and results were typically presented as the multiple of times the tolerance level was exceeded. The Unit III and IV Progress Report for December 1945 is the first indication that daily spot samples and eight-hour continuous air samples were being collected. In the available monthly reports, results were typically reported in terms of "times the tolerance level" or multiples of 2,400 dis/min/cubic meter.

6.4 Source Term

The required source term and process information includes data on the types and quantities of specific radionuclides and machine sources present, their chemical and physical forms, and the types and frequency of operations, including controls, in which these sources were utilized. NIOSH determined that its ability to establish a reliable and meaningful source term for MCC is severely limited by a lack of information regarding the isotopic and curie content of the lead dioxide obtained from uranium ore processing that was experimented with from 1943 through 1945. From 1945 through 1949, inventories of irradiated bismuth slugs and/or production schedules for polonium-210 sources from irradiated bismuth slugs are unavailable, further restricting establishment of suitable source terms. In addition, no information has been identified that relays specific information about the laboratory research associated with other isotopes, including radium and thorium.

Although an isotopic profile of similar sludge from subsequent production at Mound is available and potentially applies to earlier operations at Monsanto (assuming the comparison is made for equal decay times), there is little information available regarding the generation, handling, shipment, and disposal of radioactive waste sludge produced from processing the bismuth slugs.

7.0 Feasibility of Dose Reconstruction for the Proposed Class

The feasibility determination for the proposed class of employees covered by this evaluation report is governed by EEOICPA and 42 C.F.R. § 83.13(c)(1). Under that Act and rule, NIOSH must establish whether or not it has access to sufficient information either to estimate the maximum radiation dose for every type of cancer for which radiation doses are reconstructed that could have been incurred under plausible circumstances by any member of the class, or to estimate the radiation doses to members of the class more precisely than a maximum dose estimate. If NIOSH has access to sufficient information for either case, then it would determine that it was feasible to conduct dose reconstructions.

In making determinations of feasibility, NIOSH begins by evaluating whether current or completed NIOSH dose reconstructions demonstrate the feasibility of estimating with sufficient accuracy the potential radiation exposures of the class. In addition, NIOSH systematically evaluates the sufficiency of different types of monitoring data, process and source or source term data, which together or individually might assure that NIOSH can estimate either the maximum doses members of the class might have incurred, or more precise quantities that reflect the variability of exposures experienced by groups or individual members of the class as summarized in Section 7.6. This approach is specified in the SEC Petition Evaluation Internal Procedures which are available at http://www.cdc.gov/niosh/ocas.

Utilizing available personal and process monitoring data (see Section 5.0) to calculate maximum, claimant-favorable potential radiation doses for unmonitored employees is appropriate and possible only if the data are of sufficient quality. In addition to determining appropriate sampling, measurement, and analytical techniques, data quality sufficiency is dependant upon confidence that the selection of monitoring locations and personnel were appropriate and included the highest exposure locations and activities throughout the evaluated time frame. Similarly, it is important to determine that exposure potential associated with activities that were not associated with MCC production activities (e.g. polonium production and process development) were also evaluated.

Results of the evaluation efforts focused on the historical personnel monitoring selection are presented in Section 7.1. Evaluations examining (separately) the availability of information necessary for reconstructing internal and external radiation doses of members of the class follow in Sections 7.2 and 7.3 of this evaluation.

7.1 Analysis of Data Sufficiency and Reliability

Performing internal and external dose reconstructions requires worker monitoring data or source term and process information. Worker monitoring data includes data from members of the proposed class, as well as data from workers outside the proposed class who were performing jobs with higher exposure potentials. Using co-worker monitoring data provides a means of calculating claimant-favorable and maximum potential radiation doses for class members who were unmonitored or have gaps in their monitoring records.

During the 1943 to 1949 timeframe at MCC, polonium bioassay monitoring results were recorded in handwritten logbooks. Discussions or summaries of the bioassay and film badge monitoring results were sometimes included in Unit III and IV Monthly Reports. The monitoring results presented in the original logbooks have been captured in the PoRecon and CEDR databases. However, the lack of bioassay data and source term information for exposures to nuclides other than polonium and the lack of neutron monitoring prevents further evaluation of these exposures at MCC at this time.

In the case of this evaluation, NIOSH has found that the internal monitoring data and source term information for nuclides other than polonium, and the available information associated with neutron exposures, are insufficient at this time for estimating internal and external radiation doses with sufficient accuracy for members of the proposed class. Therefore, further evaluation of the pedigree of the available internal (polonium) and external data was not performed.

7.2 Internal Radiation Doses at Monsanto Chemical Company

From 1943 through 1949, MCC conducted research and developed processes for producing polonium-210, and ultimately, began larger-scale production of polonium neutron sources for use as initiators for nuclear weaponry. The principal source of internal radiation doses for members of the proposed class was inhalation of airborne dust containing polonium-210, which was produced by both handling lead dioxide and dust generated as a result of physical manipulation and chemical processing of irradiated beryllium slugs. Although a complex array of particulates, aerosols, dusts, and fumes may have been present during MCC operations, polonium-210 is identified as a primary radiological concern because it was frequently used at the MCC facilities in multiple buildings and facility processes. Also, polonium-210 can deliver relatively high doses (ORAU-TKBS-0016-5).

During the earliest years of MCC research and development (1943 through1945), when the Dayton Project gained access to reliable sources of irradiated beryllium, uranium isotopes (U-238, U-235, U-234, and U-233) were also considered as potential sources of internal radiation exposure from inhalation. In addition, short-lived radioactive gases and their respective daughter products (from activities involving lead dioxide and separation activities or the manufacturing of sources) were also potentially present at MCC. The polonium extraction from lead dioxide processes were discontinued after January 1945 when irradiated bismuth became the sole source of polonium (Wolf, 1945).

It is important to note that the lead dioxide, the bismuth, and aluminum contained impurities, such as antimony-124; bismuth-210; cesium-137; cobalt-60; iron-55 and -59; lead-210; mercury-203; polonium-208 and -209; selenium-75; silver-112; strontium-90; tellurium-121 and -132; tin-121; and zinc-65. NIOSH found that urine bioassay for polonium was performed and reported, but no other nuclides were included in the MCC monitoring programs.

Both chronic and acute internal exposures occurred over the course of MCC operations. The primary intake mode would have been chronic in nature and generally associated with chemical separation activities or source manufacture. Acute intakes would likely have been caused by non-routine incidents involving the release of radioactivity.

Documentation of incidents in the earliest years is typically limited to reports of elevated urine activity and specific information describing the exposure scenarios is minimal. An example of this is a paragraph included in the June 16 through June 30, 1944 Unit III Progress Report as noted below:

The two questionable cases of one chemist with high activity urine count and another chemist with a low blood count were discussed in detail. In both cases, these conditions are being closely watched and will be rechecked upon return of these men from their perspective vacations. The final decision by the medical group will be determined at that time. The man with the high activity count has been requested to mail in a daily urine sample during the second week of his vacation.

Statements in a later report dated July 5, 1944 indicate results of an investigation that followed:

Mr. M. worked on the volatilization process for six weeks but in the past two months has worked only on material of low activity, on the advice of Dr. Baker, the project physician. There have been no unusual findings on physical examinations. Five routine urinalysis have not shown abnormalities. The white counts have been of interest. Three urine specimens have been run for alpha activity and have given consistently low values.

Dr. N. worked on the lead process for about two months. The past four months he has worked in electro-deposition in charge of production. He prepares the final electrode for shipping and does the *packing. This electrode may have as much as two curies of activity. Dr. N.'s physical examinations, routine urinalysis, and blood counts have not been abnormal. Counts made on his urine have been on the order of 5,000 per minute for a 24-hour sample in each of several specimens examined.*

It seems likely that if the possibility of the specimen becoming contaminated is reduced to a minimum, the urine counts may provide a better index of absorption than changes in the blood count. It would seem reasonable to assume that in chronic exposures, an appreciable amount of Dayton product would be excreted for some time before changes appear in the blood count. For that reason, there may be more cause for concern in the case of Dr. N. than for Mr. M. Experience for interpreting the results of blood counts made elsewhere would indicate that counts as low as Mr. M.'s possibly might be normal and the first count elevated as the result of some minor infection.

Another typical example of an acute incident documented in the April 1-30, 1948 Monthly Report states:

On Thursday, April 22, 1948, a chemist at Unit IV spilled a small amount of a hydrochloric acid solution which contained a small amount of polonium on his coveralls. The chemist did not realize that the solution had soaked through his coveralls onto his leg, therefore, he did not report the accident at the time.

On Monday morning, April 26, 1948, the chemist reported to the nurse with a first degree burn above his right knee. A check made by the Health Division revealed that the burned area was also contaminated.

The burned area was cleaned by the nurse until no loose contamination was present, however, a direct reading still gave a positive result. After being cleaned, the burned area was bandaged and dressed by the nurse, and the man was barred from entering operating areas.

Two urine samples were submitted by the chemist on April 26, 1948 and April 28, 1948. Both samples were less than 12c./min/50 ml.

On the basis of the above data, the man will be permitted to return to his work in the operating areas on Monday, May 3, 1948.

Based on information included in the documentation that NIOSH reviewed for this evaluation, during its operational period, MCC used area access controls (designated/isolated work areas, gloves, vented fume hoods, and glove boxes), personnel protective equipment, and engineering controls to limit worker exposure.

The following subsections summarize the extent and limitations of information available for reconstructing internal doses of members of the proposed class.

7.2.1 Worker Monitoring Data at MCC

Although MCC workers were monitored at various times throughout MCC operations, available MCC worker monitoring data are incomplete. From 1944 through 1949, workers were monitored (primarily by urinalysis) for internal exposures to polonium; *in vivo* methods were unavailable until the late 1950's. Prior to 1944, there appears to have been no urine bioassays performed (MJW, 2002).

In any case, urine bioassays for polonium were conducted at MCC beginning in 1944, using routinely collected urine samples taken as weekly spot samples from operations personnel (Meyer, 1992). Administrative personnel were not monitored and monitoring was discontinued for operational personnel if their work on specific projects was no longer needed. For workers involved in radiological processes, routine bioassay monitoring included collection of spot and 24-hour urine samples. Individuals identified as being involved in an internal exposure incident were required to submit additional 24-hour urine samples for analysis (ORAUT-TKBS-0016-5). Historical documentation indicates that blood and fecal samples were collected at MCC but few of these data are available (Meyer, 1992).

Polonium urinalysis data are available for some MCC workers for the years 1944 through 1949. However, while the PoRecon Database contains 59,000 bioassay results for approximately 1,600 individuals prior to January 1, 1950, because there was a period of operational overlap, many of the samples cannot be differentiated between those samples related specifically to MCC and those related to the Mound Laboratory. In addition, the majority of data is for the years of production at Mound as opposed to the data for the production years at MCC.

Urine samples were initially treated without HNO3 digestion. Polonium in raw urine samples was spontaneously deposited on nickel disks and counted using a low background proportional counter. Using an improved method with acid digestion, spot urine samples of 50 ml were collected each week and preserved with 50 mg of sulfamic acid before analysis. Preserved polonium samples were digested in the plating cell with nitric acid or hydrochloric acid to produce a 1 N final solution before a two-hour electro-deposition plating time. Electro-deposition was conducted primarily on one-inch copper disks within a few hours of collection. Additional information relating to the assumptions that are applied to polonium urinalysis counts are relayed in the Mound Occupational Internal Dose Technical Basis Document (ORAUT-TKBS-0016-5).

Based on this review, NIOSH has identified that it is feasible to use the available worker monitoring data to provide a bounding polonium internal dose to MCC workers. Although potential models for reconstructing the internal dose for radionuclides other than polonium have been identified, it is not clear to NIOSH how much additional data and time will be required to complete these models to support dose reconstruction with sufficient accuracy, nor does NIOSH have complete confidence based on the existing availability of data that dose reconstruction can be completed with sufficient accuracy. Therefore, NIOSH has concluded that it is not feasible to determine a bounding dose estimate for the internal exposures to nuclides other than polonium.

7.2.2 Process and Source Term Information at MCC

Routine air monitoring data can sometimes be used to place bounding estimates on intakes of radioactivity and hence internal doses. However, dose reconstruction for MCC is compromised by limited available process monitoring and source term information. In addition, there are few records of systematic air monitoring for radioactivity during the early years of the project, and even if there were sufficient data available, there are no reliable records to indicate the specific times that a worker might have spent in a particular location. Air sampling results were analyzed using gross alpha counting, with all alpha activity assumed to have been attributable to polonium-210. The available data are far too limited to provide a reliable indication of intake. Reliable source term information is largely lacking and therefore of limited utility in determining intakes and internal doses.

The required source term and process information includes data on the types and quantities of specific radionuclides and machine sources present, their chemical and physical forms, and the types and frequency of operations, including controls, in which these sources were utilized. NIOSH determined that its ability to establish a reliable and meaningful source term for MCC is severely limited by a lack of information regarding the isotopic and curie content of the lead dioxide that was experimented with from 1943 through 1945. From 1945 through 1949, inventories of irradiated bismuth slugs and/or production schedules for polonium-210 sources from irradiated bismuth slugs are unavailable, further restricting establishment of suitable source terms. There is no information regarding how much of each isotope was used in the production of alpha and neutron sources. Furthermore, although an isotopic profile of similar sludge from subsequent production at Mound is available and potentially applies to earlier operations at Monsanto (assuming the comparison is made for equal decay times), there is little information available regarding the generation, handling, shipment, and disposal of radioactive waste sludge produced from processing the bismuth slugs.

7.2.3 Ambient Environmental Internal Doses at MCC

As discussed in the *Technical Basis Document for the Mound Site—Occupational Environmental Dose*, the available Dayton Unit III and IV data consist of Progress Reports for July, August, September, October, and December 1945; Monthly Health Reports for November and December 1947; and Monthly Health Reports for January and March 1948. No data was available for 1943, 1944 and 1946. Available data indicate that by 1947, gross alpha air sampling was being conducted in both the indoor and outdoor areas of Dayton Units III and IV. All gross alpha air sample results were assumed to be due to polonium-210. A review of the available air sample results for Dayton Units III and IV in 1945, 1947, and 1948 indicate that airborne concentrations of polonium-210 in the operational areas of Units III and IV unit were very similar. In 1945, clean area and hallway air sampling results at both units III and IV were typically between 0.1 and 0.5 times the acceptable "tolerance" (permissible) level of 2,400 dpm/m3 or between 1.08E-10 to 5.40E-10 uCi/ml.

In addition, the outdoor site perimeter air monitoring results from Units III and IV in November and December 1947, January 1948, and March 1948 are comparable. In March 1948, gross alpha levels outside Unit III averaged 1.08E-11, while the levels outside Unit IV averaged 1.62E-10. The weekly outdoor perimeter air samples for Dayton Unit III during the month of December 1947 are the highest outdoor air monitoring data available for the Dayton Units. Due to the lack of available environmental air monitoring data for the Dayton Units, the environmental intakes for both Dayton Units III and IV have been determined using the December 1947 and Dayton Unit III data. The median polonium-210 outdoor perimeter airborne concentration for Unit III was 4.86E-10 uCi/ml and is assumed to be applicable to Dayton Units III and IV for the time period of November 1944 through 1948. The air sampling data is also assumed to incorporate the re-suspension component due to any soil contamination that may have been present.

Environmental intakes are assumed to have occurred beginning in November 1944 when actual polonium-210 production started at Units III and IV (Wolf, July 1945; August 1945; October 1945; and December 1945). Annual polonium-210 inhalation intakes are the product of the median polonium-210 environmental air concentration and 2,400 m3/yr, which is the product of the breathing rate (1.2 m3/hr) of a reference man doing light work and an exposure duration of 2,000 hr/year. Below, Table 7-1 presents the annual environmental intakes at the Dayton Units. Because there was no polonium production at Dayton Unit I and the work conducted at Unit I involved relatively small quantities of carbon-4, tritium, and polonium-210 in dispersible form, Unit I environmental polonium intakes are assumed to be a factor of 1,000 times less than the Unit III and IV intakes. Polonium is assumed to account for 95% of the internal dose. The most claimant favorable absorption type will be selected for dose reconstruction because of the various chemical forms of polonium that may have been used at the Dayton facilities.

Table 7-1: Annual Polonium-210 environmental intakes at Dayton Units I, III, and IV[1]

Year	Unit 1 Intake (Bq)	Unit 1II Intake (Bq)	Unit 1V Intake (Bq)
1944[2]	6.91	6,912	6,912
1945	43.20	43,200	43,200
1946	43.20	43,200	43,200
1947	43.20	43,200	43,200
1948	43.20	43,200	43,200

Notes:
[1] Apply Mound ambient environmental polonium-210 intakes for 1949 per ORAUT-TKBS-0016-4.
[2] Based on 8 weeks of polonium-210 production in 1944.

An estimate of the uncertainty associated with the median environmental intakes presented in Table 7-1 has been made by assuming that the intakes are lognormally distributed and that the median intakes in Table 7-1 represent the 50th percentile intake rate. The intake from exposure to the tolerance level of 2,400 dpm/m3 (96,000 Bq in each year from 1945 to 1948) for units III and IV and 0.1% of the tolerance level for Unit I are assumed to represent the upper 95th percentile intake.

The methodology for evaluating the bounding ambient environmental dose through the application of these intakes is described in *Technical Basis Document for the Mound Site-Occupational Environmental Dose* (ORAUT-TKBS-0016-4). Based on this information, NIOSH can reconstruct the ambient environmental dose due to polonium for the class of MCC workers defined in this evaluation report with sufficient accuracy. Although a method to estimate the ambient environmental internal dose from the nuclides other than polonium could possibly be established using assumed isotopic ratios, NIOSH has concluded that it is not feasible to determine a bounding dose estimate for these exposures in a timely manner based on the available data.

7.2.4 Internal Dose Reconstruction Feasibility Conclusion

NIOSH has determined at this time there is a lack of sufficient monitoring and source term data for nuclides other than polonium between 1943 and 1949 at MCC. Although polonium bioassay data used in conjunction with co-worker data from Mound Laboratory and ambient environmental polonium internal intakes could be used to support internal dose reconstruction, due to lack of information and internal exposure data for the use and production of radionuclides other than polonium, NIOSH has concluded that there are insufficient data available to support internal dose reconstructions with sufficient accuracy at MCC for the time period 1943 through 1949. This inability to complete internal dose reconstruction at MCC for the 1943 through 1949 time period is because of a lack of information and internal exposure data for radioisotopes other than polonium, such as antimony-124; bismuth-210; cesium-137; cobalt-60; iron-55 and -59; lead-210; mercury-203; polonium-208 and -209; selenium-75; silver-112; strontium-90; tellurium-121 and -132; and tin-121; as well as radium and thorium.

As a result of these limitations, NIOSH cannot establish a maximum internal exposure scenario in a timely manner that addresses all of the internal exposure potential for the petitioning class, and therefore, cannot estimate internal doses for members of the class with sufficient accuracy.

7.3 External Radiation Doses at Monsanto Chemical Company

The principal source of external radiation doses for members of the proposed class included beta, photon, and neutron radiation associated with bismuth slugs which had been irradiated with neutrons to produce polonium-210 (ORAUT-TKBS-0016-6). Neutron irradiation of bismuth slugs began in 1944, and after January 1946 became the sole source of polonium-210. Prior to that time, polonium-210 had been concentrated and isolated from natural sources. Radioisotopes associated with the lead dioxide also include those from the entire uranium-238 decay chain. Natural polonium-210 decays to stable lead-206 by alpha emission with virtually no associated photon radiation, emitting only a 0.803 MeV gamma ray with a miniscule yield of only 1.1 x 10-5, so that polonium-210 separated from natural sources would not produce a significant external radiation field. In addition to the polonium-210 external exposure issue, there was also an external exposure component associated with the handling of uranium and uranium progeny during the early years. Other radioisotopes associated with production of polonium from lead dioxide also include those from the entire uranium-238 decay chain.

However, this is not true for polonium-210 produced from neutron bombardment of bismuth. Naturally occurring bismuth contains only the bismuth-209 isotope, which, upon neutron bombardment, transmutes to bismuth-210. Bismuth-210 is a beta-emitting isotope with a half-life of 5.01 days, and it decays to polonium-210. Intense beta fields are associated with irradiated bismuth (Ferry, 1944). Photon fields associated with the decay of bismuth-210 are minimal, largely deriving from weak characteristic X-rays of polonium. However, significant external photon fields may have existed as a result of the presence of activation products. Neutrons are produced by the (alpha-n) reaction on light elements (specifically beryllium) from interaction with the 5.3 MeV alpha particles associated with the decay of the 138-day polonium-210. Thus, there are external beta, photon, and neutron fields associated with polonium-210.

Workers were required to undergo medical screening X-rays as a condition of employment, which resulted in additional external exposure detailed in Section 7.3.3 below.

7.3.1 Worker Monitoring for External Radiation Doses at MCC

The following subsections summarize the extent and limitations of information available for reconstructing the external doses of members of the proposed class.

7.3.1.1 External Beta-Photon Radiations

Film badges and pocket ionization chambers were utilized to monitor external radiation doses to MCC workers. Until February 1949, only production workers were issued film badges (ORAUT-TKBS-0016-6). Initially, the dosimeter holder was either a ring or brass badge containing a dental X-ray film. However, by August 1946, Kodak dental films were used with an unspecified holder or badge and rings contained a hand-cut disk of film. In February 1949, for the purpose of providing a broad measurement range, a change was made to the DuPont 552 packet which contained two pieces of film, one for high sensitivity and the other for low sensitivity. This DuPont packet was used in conjunction with the Oak Ridge steel holder. The Oak Ridge holder had an open window through which beta particles and low energy photons could reach the film, as well as a cadmium metal filter to minimize photon energy dependence.

Beginning in 1944, MCC recorded film badge doses. Initially, results were entered with a code rather than the worker name, but with the exception of two names entered for the week of July 19, 1946, the code-name listing is not available (ORAUT-TKBS-0016-6). Recording of doses by worker name began with the work week ending January 17, 1947.

NIOSH has located external dosimetry records of measured beta and photon exposure to the extremities and/or whole body, beginning in 1944, that can be used to form a co-worker basis for completing sufficiently accurate external dose reconstructions for beta-photon exposures. The existence of the measured dose data does provide realistic options to assure the dose to workers is not under-estimated. Based on the information obtained and reviewed during this evaluation, there is an expectation that recorded external monitoring data is available for an individual worker, and the information may be used in addition to recorded monitoring data for other workers, such that NIOSH can reconstruct external beta-photon doses for members of the proposed class with sufficient accuracy.

7.3.1.2 Neutron Exposure

The workers associated with polonium research and neutron source production in the Dayton units had the highest potential for exposure to neutrons. Although the potential for personnel exposure to neutrons existed at MCC for the time period of 1943 through 1949, personnel neutron monitoring did not begin at MCC until September 1949 (Meyer, 1994 and ORAUT-TKBS-0016-6). Thus, while the potential for exposure to neutrons existed at MCC, NIOSH has insufficient information, relating to source term information for the polonium or neutron source production work, to characterize possible neutron fields or energies. Therefore, NIOSH cannot estimate the potential neutron exposures with sufficient accuracy for this proposed class as evaluated in this report. Although potential models for reconstructing the external exposure from neutrons have been identified, it is not clear to NIOSH how much additional data and time will be required to complete these models to support dose reconstruction with sufficient accuracy nor does NIOSH have complete confidence based on the existing availability of data that dose reconstruction can be completed with sufficient accuracy. Therefore, NIOSH has concluded that it is not feasible to determine a bounding dose estimate for these exposures based on the available data in a timely manner.

7.3.2 Ambient Environmental External Radiation Doses at MCC

As indicated in the *Technical Basis Document for the Mound Site—Occupational Environmental Dose*, no documentation of direct gamma radiation outside of the Dayton Facilities is available

(ORAUT-TKBS-0016-4). The only documentation of a control badge result is for the week of May 17 to May 23, 1944, when a control badge result of 0.13 Roentgen (0.9 mR/h) was reported. Assuming that the control badge data is representative of ambient dose rate outside the Dayton Facilities, the resulting dose for 2,000 hours of occupational exposure is 1,800 mrem.

For 1945 through 1948, an estimate of the uncertainty associated with the ambient dose has been made by assuming that the ambient dose is lognormally distributed and that the median annual dose of 1.80 cSv represents the 50th percentile dose. Exposure to the tolerance or permissible level of 15 cSv per year is assumed to represent the upper 95th percentile dose. For 1944, an estimate of the uncertainty associated with the ambient dose has been made by assuming that the ambient dose is lognormally distributed and that the median annual dose of 0.29 cSv represents the 50th percentile dose. Exposure to the tolerance level 0.5 cSv (500 mrem) per 40-hour week for eight weeks (4.0 cSv) is assumed to represent the upper 95th percentile dose. Mound ambient environmental external doses for 1949 are applied per *Technical Basis Document for the Mound Site—Occupational Environmental Dose* (ORAUT-TKBS-0016-4).

The methodology for applying this dose as an upper bounding ambient environmental external dose is described in the *Onsite Ambient Dose Reconstruction Procedure*. Based on the information in the Mound Site Profile and the procedure, NIOSH can reconstruct the ambient environmental dose for the class of MCC workers defined in this evaluation report with sufficient accuracy.

7.3.3 Occupational X-Ray Examinations at MCC

As revealed in the NIOSH review of the current individual claims and the SRDB, very little information exists concerning medical X-rays at MCC during the class period. The Mound Occupational TBD reports that from 1946 to the end of MCC operations in 1949, X-rays were required both annually and at termination. Based on the standard medical practice of that time, the frequency of chest X-ray exams prior to 1946 can be assumed to be the same as for the years 1946 through 1949. Using the identified periodicity, an upper bound for exposure for occupational X-rays can be established using the procedure, *Occupational X-Ray Dose Reconstruction for DOE Sites* (ORAUT-PROC-0061). In summary, NIOSH can reconstruct the medical X-ray dose for the class of MCC workers in the class defined in this evaluation report with sufficient accuracy.

7.3.4 External Dose Reconstruction Feasibility Conclusion

Based on the information and evaluation presented throughout Section 7.3, NIOSH finds that the available external monitoring data are insufficient to reconstruct the external neutron doses with sufficient accuracy for all members of the proposed class for the period 1943 through 1949.

NIOSH has located external dosimetry records for measured beta and photon exposure to the extremities and/or whole body, beginning in 1944 that can form a co-worker basis for bounding dose reconstruction. The existence of the measured dose data provides realistic options to assure the beta and photon dose to workers is not under-estimated. However, as discussed in 7.3.1.2, although potential models for reconstructing the external exposure from neutrons have been identified, it is not clear to NIOSH how much additional data and time will be required to complete these models to support dose reconstruction with sufficient accuracy nor does NIOSH have complete confidence based on the existing availability of data that dose reconstruction can be completed with sufficient accuracy.

Therefore, NIOSH has concluded that it is not feasible to determine a bounding dose estimate for these exposures based on the available data in a timely manner.

Based on the information and evaluation presented throughout Section 7.3, NIOSH finds that with the exception of the external beta-photon, ambient environmental external, and the medical X-ray doses, the available external monitoring data are insufficient to reconstruct the external doses with sufficient accuracy for all members of the proposed class for the period 1943 through 1949.

7.4 Evaluation of Petition Basis for SEC-00049

The following subsection evaluates the assertions made on behalf of petition SEC-00049 for the Monsanto Chemical Company.

7.4.1 Evaluation of General Concerns Raised in Petition SEC-00049

The following addresses general concerns raised pursuant to petition SEC-00049.

7.4.1.1 Lack of Monitoring

The petitioner included Form B, Item F.1 as the petition basis, indicating that radiation exposures and radiation doses potentially incurred by members of the proposed class were neither monitored through personal monitoring nor through area monitoring (Affidavit, 2006). Although NIOSH has determined that internal exposures from polonium and external exposures from beta-photon exposures, occupational medical X-rays, and ambient environmental sources can be reconstructed, NIOSH has determined that there was a lack of occupational internal monitoring for isotopes other than polonium and lack of external monitoring data for worker exposures to neutron radiations for the period evaluated in this petition.

7.4.1.2 Questionable Monitoring Practices

The petitioner uses the pamphlet titled *History of the Dayton Project* to support the basis for the petition. The pamphlet states that “Radioactivity in the laboratory had to be carefully controlled. Here scientists were working with the largest amounts of polonium ever isolated, and the associated radioactivity was significant. Employees who were exposed to significant amounts of radioactivity on a daily basis were checked regularly both for their own health, and to assure that no contamination was leaving the laboratory and entering the community (Gilbert, 1969).”

The referenced document indicates that a control program was in place and the historical record indicates that MCC implemented a health physics program intended to reduce worker exposures to radiation. Even though the elements of health physics programs were in place, NIOSH found that information regarding operational technology, instrumentation, and documentation of practices and data, was insufficient to support dose reconstruction in a timely manner.

7.5 Summary of Feasibility Findings for Petition SEC-00049

This report evaluated the feasibility for completing dose reconstructions for employees at the Monsanto Chemical Company from January 1943 through December 1949. NIOSH found that although potential models for reconstructing the internal dose for radionuclides other than polonium and the external exposure from neutrons have been identified, it is not clear to NIOSH how much additional data and time will be required to complete these models to support dose reconstruction with sufficient accuracy nor does NIOSH have complete confidence based on the existing availability of data that dose reconstruction can be completed with sufficient accuracy. Therefore, NIOSH has concluded the monitoring records, process descriptions, and source term data available are not sufficient to carry out complete dose reconstructions with sufficient accuracy for the proposed class of employees.

Table 7-2 summarizes the results of the feasibility findings at Monsanto Chemical Company for each exposure source for the time period January 1943 through December 1949.

Table 7-2: Summary of Feasibility Findings for SEC-00049

January 1943 through December 1949

Source of Exposure	Reconstruction Feasible	Reconstruction Not Feasible
Internal		
- Occupational Polonium	X[1]	
- Occupational Non-Polonium		X[1]
- Ambient Environmental (polonium)	X[2]	
- Ambient Environmental (non-polonium)		X[2]
External		
- Alpha	X	
- Beta	X	
- Neutron		X[3]
- Photon	X	
- Occupational Medical X-ray	X	
- Ambient Environmental	X	

Notes:
[1] Dose reconstruction is considered feasible for polonium only; bioassay data are not available for any other isotopes.
[2] Dose reconstruction is considered feasible for polonium only; ambient environmental data are not available for any other isotopes.
[3] Dose reconstruction is not considered feasible for neutron exposures. However, NIOSH has concluded that an approach to estimate these exposures could be developed.

8.0 Evaluation of Health Endangerment for Petition SEC-00049

The health endangerment determination for the class of employees covered by this evaluation report is governed by EEOICPA and 42 C.F.R. § 83.13(c)(3). Under these requirements, if it is not feasible to estimate with sufficient accuracy radiation doses for members of the class, NIOSH must also determine that there is a reasonable likelihood that such radiation doses may have endangered the health of members of the class. Section 83 requires NIOSH to assume that any duration of unprotected exposure may have endangered the health of members of a class when it has been established that the class may have been exposed to radiation during a discrete incident likely to have involved levels of exposure similarly high to those occurring during nuclear criticality incidents. If the occurrence of such an exceptionally high-level exposure has not been established, then NIOSH is required to specify that health was endangered for those workers who were employed for a number of work days aggregating at least 250 work days within the parameters established for the class or in combination with work days within the parameters established for one or more other classes of employees in the SEC.

This NIOSH evaluation did not identify any evidence from the petitioner or from other resources that would establish that the class was exposed to radiation during a discrete incident or similar conditions resulting from the failure of radiation exposure controls likely to have produced levels of exposure similarly high to those occurring during nuclear criticality incidents. NIOSH is not aware of any report of such an occurrence at the facility during this period. NIOSH finds that the primary radiation exposure hazards to employees resulted from chronic exposures from inhalation and ingestion of radionuclides, combined with external exposures to gamma, beta, and neutron radiation. Consequently, NIOSH is specifying that health may have been endangered for those workers covered by this evaluation who were employed for a number of work days aggregating at least 250 work days within the parameters established for this class or in combination with work days within the parameters established for one or more other classes of employees in the SEC. A modification of the class definition regarding health endangerment and minimum required employment periods was not required.

9.0 NIOSH-Proposed Class for Petition SEC-00049

Based on its research, NIOSH modified the petitioner-requested class to define a single class of employees for which NIOSH cannot estimate radiation doses with sufficient accuracy. The NIOSH-proposed class includes: A*ll Atomic Weapons Employer employees who were monitored or who should have been monitored for radiation while working at Monsanto Chemical Company Units I, III, or IV in Dayton, Ohio for a number of work days aggregating at least 250 work days during the period from January 1, 1943 to December 31, 1949*. The class was modified in order to specify MCC units which conducted Manhattan Engineer District operations and to delineate the timeframe for which the operations occurred.

NIOSH has carefully reviewed all material sent in by the petitioner, including the specific assertions stated in the petition, and has responded to them herein (see Section 7.4). NIOSH has also reviewed the available technical resources and many other references, including the Site Research Data Base (SRDB) for information relevant to SEC-00049. In addition, NIOSH reviewed its dose reconstruction database, NIOSH OCAS Claims Tracking System (NOCTS), to identify dose reconstructions under EEOICPA that might provide information relevant to the petition evaluation.

These actions are based on existing, approved NIOSH processes used in dose reconstruction for claims under EEOICPA. NIOSH's guiding principle in conducting these dose reconstructions is to ensure that the assumptions used are fair, consistent, and well-grounded in the best available science. Simultaneously, uncertainties in the science and data must be handled to the advantage, rather than to the detriment, of the petitioners. When adequate personal dose monitoring information is not available, it is often feasible to estimate doses by using additional information that might be available (area monitoring results, information regarding radiological sources, information regarding work processes involving radiological exposures, and monitoring information from comparable operations at other facilities). When using such additional information, radiation estimates typically overestimate, within plausible limits, the likely actual exposures and doses of employees at the facility. NIOSH has attempted to comply with these standards of performance in determining that it would not be feasible to reconstruct the dose for the class proposed for this petition.

10.0 References

42 C.F.R. 81, *Guidelines for Determining the Probability of Causation Under the Energy Employees Occupational Illness Compensation Program Act of 2000;* Final Rule, Federal Register/Vol. 67, No. 85/Thursday, p 22296; May 2, 2002; SRDB Ref ID: 19391

42 C.F.R. 82, *Methods for Radiation Dose Reconstruction Under the Energy Employees Occupational Illness Compensation Program Act of 2000*; Final Rule; May 2, 2002; SRDB Ref ID: 19392

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