# SEC Petition Evaluation Report
## Petition SEC-00012-1

Report Rev # ___Draft                Report Submittal Date __________

| Petition Administrative Summary | | | |
|---|---|---|---|
| **Petition Under Evaluation** | | | |
| Petition # | Petition Type | Submittal Date | DOE/AWE Facility Name |
| SEC-00012 | 83.13 | 07-21-2004 | Mallinckrodt |

| Feasible to Estimate Doses with Sufficient Accuracy? | | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|
| Single class | | | | Multiple classes | | | | Determination Established for All Classes? | | | |
| Yes | | No | | Yes | | No | X | Yes | | No | X |

| **Initial Class Definition** |
|---|
| The entire uranium division of Mallinckrodt Chemical Works (1942-1957) |

| **Proposed Class Definition** |
|---|
| All DOE, DOE contractors, or subcontractors, or AWE employees who worked in the Uranium Division at the Mallinckrodt Destrehan Street facility during the period from 1942 through 1945. |

| **Related Petition Summary Information** | | | |
|---|---|---|---|
| SEC Petition Tracking #(s) | Petition Type | DOE/AWE Facility Name | Petition Status |
| NA | NA | NA | NA |

| | | |
|---|---|---|
| **Lead Technical Evaluator:** | **Signature on File**<br>*LaVon B. Rutherford* | *Date* |
| **Peer Review Completed By:** | **Signature on File**<br>*James W. Neton* | *Date* |
| **SEC Petition Evaluation Approved By:** | **Signature on File**<br>*Larry J. Elliott* | *Date* |

## Evaluation Summary

This evaluation report by the National Institute for Occupational Safety and Health (NIOSH) covers a subset of the employees initially proposed as a class for addition to the Special Exposure Cohort (SEC) in SEC Petition No. 12, qualified on November 24, 2004. Although the petition requested NIOSH to consider all workers within the Uranium Division at the Mallinckrodt Destrehan Street facility in St. Louis, Missouri, over the entire period of operation from 1942 through 1957, this evaluation is limited to those Uranium Division employees working from 1942 through 1945. The current evaluation addresses all Uranium Division workers including those employed directly or under contract by the Manhattan Engineering District /Atomic Energy Commission (MED/AEC) for radioactive material processing or for research. NIOSH is continuing its evaluation for the remainder of workers (1946 through 1957) at the Mallinckrodt facility covered by SEC Petition No. 12.

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). Under these requirements, NIOSH must establish whether or not it has access to sufficient information to either estimate the maximum radiation dose that could have been incurred under plausible circumstances by any member of the class, or to estimate the radiation doses of members of the class more precisely than a maximum dose estimate. If NIOSH were to have access to the information sufficient for either case, then dose reconstruction would be feasible.

NIOSH has established in this evaluation that it lacks 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. NIOSH has queried all recognized sources of data concerning the operations at the facility. The majority of the data identified is summarized in the site profile for the facility. The sum of information available from the site profile and additional resources is insufficient to document or estimate the maximum air concentrations of respirable, radionuclide dusts and radon gas that were generated and hence could have been inhaled and/or ingested by members of the class, resulting in internal radiation doses. On this basis, NIOSH cannot reconstruct the maximum internal radiation dose received by any member of the class and hence cannot conduct complete dose reconstructions for this class of employees.

Health Endangerment

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 make a determination whether or not 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 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.

The NIOSH evaluation did not identify any evidence from the petitioners or from other resources that would establish that the class was exposed to radiation during a discrete incident likely to have involved exceptionally high level exposures, as described above. NIOSH is not aware of any report of such an occurrence at the facility. Evidence presented by the petitioner and uncovered by NIOSH associates the hazard to episodic inhalations of radionuclides that cumulatively result in chronic exposures. Consequently, NIOSH has specified that health was 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.

Proposed Class Definition

This evaluation defines a single class of employees for which NIOSH cannot estimate radiation doses with sufficient accuracy and whose health may have been endangered by such radiation doses. This class includes employees of DOE or DOE contractors or subcontractors employed by the Uranium Division of Mallinckrodt during the period from 1942 through 1945 and whom were employed for a number of work days aggregating at least 250 work days within these three plants or in combination with work days within the parameters (excluding aggregate work day requirements) established for classes of employees presently included in the SEC. This proposed class definition includes all such employees of DOE or DOE contractors or subcontractors who worked within the three plants, irrespective of job title or job duty.

In consultation with the Division of Energy Employees Occupational Illness Compensation, Department of Labor, NIOSH has determined that Plants 1, 2, and 4 are functionally equivalent to that portion of the Mallinckrodt Destrehan Street facility known as the Uranium Division, and has therefore proposed a class definition that utilizes that designation.

## 1.0 Purpose

The purpose of this report is to provide an evaluation of the feasibility of reconstructing the doses for a subset of the employees proposed as a class in SEC Petition No. 12 at the Mallinckrodt Destrehan Street facility in St. Louis, Missouri. Although NIOSH has not completed its evaluation with respect to all employees proposed for coverage under SEC Petition No. 12, NIOSH is issuing this report because NIOSH has established that it cannot conduct complete dose reconstructions for the class of DOE or DOE contractors or subcontractors employees who worked at the Mallinckrodt Destrehan Street facility within Plants 1, 2, or 4 during the period from 1942 through 1945. NIOSH has also made a health endangerment determination with respect to this class of employees. Issuing a report of these findings immediately will allow the Advisory Board on Radiation and Worker Health (the Board), the Director of NIOSH, and the Secretary of HHS to make recommendations and decisions concerning this class of employees, as provided under 42 C.F.R. Part 83, without delay.[1]

This evaluation was conducted in accordance with the requirements of EEOICPA, 42 C.F.R. Part 83, and the guidance contained in NIOSH's Internal Procedures for SEC Evaluations, OCAS-PR-004. It provides information and analyses germane to considering a petition for adding a class of employees to the SEC. It does not provide any determinations concerning the feasibility of dose reconstruction that necessarily apply in the particular case of any individual energy employee who might require a dose reconstruction from NIOSH.

## 2.0 Introduction

EEOICPA and 42 C.F.R. Part 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*, requires NIOSH to evaluate qualified petitions requesting HHS to add a class of employees to the SEC. The evaluation is intended to provide a fair, science-based determination of whether or not it is feasible to estimate with sufficient accuracy the radiation doses of the class of employees through NIOSH dose reconstructions.[2] If it is not feasible, the regulation requires NIOSH to make a determination with respect to the health endangerment of the class of employees.

NIOSH is required to document the evaluation in a report, which is provided to the petitioners and to the Board. The Board will consider the NIOSH evaluation report, together with the petition, comments of the petitioner(s), and such other information as the Board considers appropriate, 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 decisions on behalf of HHS. The Secretary of HHS will make final decisions, taking into account the NIOSH evaluation, the advice of the Board, and the proposed decision issued by NIOSH. As part of this final decision process, the petitioner(s) may seek a review of certain types of proposed decisions issued by NIOSH.[3]

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[1] NIOSH has separately completed an evaluation of the feasibility of dose reconstruction and a health endangerment determination, if necessary, for employees of this facility who worked during the subsequent time periods 1946-1948 and 1949-1957 covered by SEC Petition No. 12. That evaluation is reported in SEC Petition Evaluation Report SEC-00012-2.
[2] NIOSH dose reconstructions under EEOICPA are performed using the methods promulgated under 42 C.F.R. Part 82 and the detailed implementation guidelines available at www.cdc.gov/niosh/ocas.
[3] See 42 C.F.R. Part 83 for a full description of the procedures. Additional internal procedures are available at www.cdc.gov/niosh/ocas.

This present NIOSH report provides a summary of the methods and findings of the NIOSH SEC petition evaluation for employees of DOE or DOE contractors or subcontractors at the Mallinckrodt Destrehan Street facility in St. Louis, Missouri, within Plants 1, 2, or 4, over the period of operation from 1942 through 1945. These three plants conducted radioactive material processing and related research for MED/AEC.

## 3.0 Initial Class Definition and Petition Basis

SEC Petition No. 12, which qualified on November 24, 2004, requested HHS to consider the addition to the SEC of a class of employees including the entire Uranium Division at the Mallinckrodt Destrehan Street facility in St Louis, Missouri from 1942-1957.

Of the evidence provided by the petitioners, the following evidence met the criteria in the rule as evidence required to be provided in support of their belief that dose reconstruction would not be feasible for this proposed class of employees, to qualify the submission as a petition to receive consideration by NIOSH, the Board, and HHS:

- The NIOSH site profile for this facility, *Technical Basis Document: Basis for Development of Exposure Matrix for the Mallinckrodt Chemical Company St. Louis Downtown Site, St. Louis, Missouri, Period of Operation: 1942-1958*, documents that NIOSH has little personal or area monitoring data for employees who worked at the facility from 1942 until 1948.
- According to Mont Mason (notes from August 1975), internal and external exposures were misrepresented in the monitoring records during the period from (1946-1957). Mont Mason asserts that dose values of .000 were recorded in the official monitoring records when samples were not taken. This assertion is credible to NIOSH. Mont Mason was one of the original health physicists at Mallinckrodt and was employed during the time period of concern. He was likely to have been thoroughly familiar with monitoring and recording procedures at the facility. Furthermore, while recall accuracy can be an issue concerning events that occurred two decades prior, Mr. Mason made the assertion under conditions that would encourage recall and objectivity; researchers documented this assertion during a discussion with Mr. Mason for a study Oak Ridge Associated Universities (ORAU) was conducting in 1975. (This evidence will be addressed in the NIOSH SEC evaluation report covering the 1946-1957 period at Mallinckrodt, for which the evidence is germane.)

## 4.0 Data Resources

NIOSH identified and reviewed data resources to determine the availability of information relevant to determining the feasibility of dose reconstruction for the class of employees covered by the petition. This included determining the availability of information on personal monitoring, area monitoring, industrial process, and radiation source materials. The following sections identify the resources identified and reviewed.

## Site Profile or Technical Basis Documents

NIOSH reviewed portions of the site profile NIOSH issued on October 24, 2003 for the facility covered by the petition: *Technical Basis Document: Basis for Development of Exposure Matrix for the Mallinckrodt Chemical Company St. Louis Downtown Site, St. Louis, Missouri, Period of Operation: 1942-1958*. The Technical Basis Document (TBD) provides process history information, information on personal and area monitoring, radiation source descriptions, and references to primary documents relevant to the radiological operations at the facility.

## Previous Dose Reconstructions

NIOSH reviewed its dose reconstruction database, NIOSH OCAS Claims Tracking System (NOCTS), to identify dose reconstruction cases under EEOICPA that might provide information relevant to the petition evaluation. The table below provides the results of this review of NOCTS for the years 1942-1945.

**Mallinckrodt Cases Submitted Under Dose Reconstruction Rule for 1942-1945**

| Description | 1942 | 1943 | 1944 | 1945 | Total |
|---|---|---|---|---|---|
| Number of cases submitted for energy employees who meet the petition criteria. | 30 | 12 | 4 | 7 | 53 |
| Number of maximizing or best estimate dose reconstructions completed for energy employees who were employed at Mallinckrodt during the years identified. | 0 | 0 | 0 | 0 | 0 |
| Number of cases for which internal dosimetry records were obtained for the identified years. | 0 | 0 | 0 | 0 | 0 |
| Number of cases for which external dosimetry records were obtained for the identified years. | 0 | 0 | 0 | 0 | 0 |
| Number of cases for which area monitoring data were obtained for the dose reconstruction. | 0 | 0 | 0 | 0 | 0 |

NIOSH reviewed each case to determine whether NIOSH had been able to obtain internal and/or external personal monitoring records on the employee or area monitoring data that could be used in the place of personal data. NIOSH had not obtained any personal records or area monitoring data from the employees' records for use in these dose reconstructions. NIOSH also reviewed the interviews conducted with claimants for these cases to determine whether they had provided relevant information for dose reconstruction. The interviews provided information that might be useful for some individual dose reconstructions, but this information did not substantially improve the general dose-related information available concerning the proposed class.

## NIOSH and ORAU Research Documents

The NIOSH and ORAU site research databases were reviewed for documents to support the evaluation of the petitioning class. The documents identified for review from this search are listed in Attachment 1. The reports include information on dust studies, radon sampling, dose rate surveys, urinalysis data, the radiological control program, medical monitoring, feed materials, and process description information.  The information from these documents relevant to the petitioning class is summarized in sections 5.0 of this report.

**Documentation and/or affidavits provided by the Petitioners**

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

1) Letter from Denise Brock (Petitioner) to the Honorable Tommy Thompson, dated July 17, 2004.
2) NIOSH Technical Basis Document on the facility, issued October 24, 2003:  (various sections of the document are referenced in the petition).
3) Mallinckrodt Chemical Works, Subject: Concerning the Grouping of Death Certificate Cards into Exposed vs. Unexposed Groups, M. E. Mason, August 1975.
4) Urine Samples – Mallinckrodt Chemical Works dated September 20, 1951.
5) Letter from Knowlton J. Caplan to W. B. Harris Subject: Techniques of Radon Breath Sampling dated January 8, 1951.
6) Destruction of Records and Lost Medical Records dated September 5, 1972.
7) Interim Report:  MCW Evaluation of Dust Exposure, Plant 4 and Plant 6 dated October 3, 1972.
8) Document untitled and unknown origin identified as “Gaps in Present State of Knowledge.”
9) Mallinckrodt’s Uranium Operations for the U.S. Government:  MED and AEC.
10) 1951 Memorandum from Merril Eisenbud to W. E. Kelley (*Cover letter to “An Estimate of Cumulative Multiple Exposures to Radioactive Materials”)*
11) An Estimate of Cumulative Multiple Exposures to Radioactive Materials dated November 20, 1950.
12) Some Observations of Uranium Exposures within the Nuclear Industry, A.F. Becher, Consultant, ERDA Health and Mortality Study.
13) Oral History of Merril Eisenbud, United States Department of Energy Office of Human Radiation Experiments, May 1995.

These documents were reviewed as to the relevance to the petitioning class.  The information from these documents relevant to the petitioning class has been summarized in sections 5.0 and 7.0 of this report.

## 5.0 Summary of Available Monitoring Data

A paucity of individual personnel monitoring data is available for the facility prior to 1946, as observed by the Atomic Energy Commission (AEC 1950a).  The omission of a program of continuous monitoring of the radiation doses of individual personnel was based on the expectation that the processing of uranium ores and compounds would involve little risk of radiation injury (AEC 1950a). In particular, management at the time recognized the low specific activity of uranium (the relatively low level of radiation exposure emitted by uranium) and assumed the work operations (and hence exposures), which were temporary, would be brief (AEC 1950a).  There was no neutron monitoring performed at the facility but there was no potential for substantial neutron exposures.  Radiation measurements and evaluations of dust exposure during these years of operation, apparently beginning in 1943, were performed on an area-wide, episodic basis.

The following table summarizes available monitoring data from 1942 through 1945:

| Plant | Internal Dose Data | External Dose Data |
|---|---|---|
| 1 | No data were found for 1942. Some data on area dust levels for 1943-1945 and some data on radon levels are available for 1945. | No data were found for 1942. Some data on dose rates for various work locations are available for 1943-1945. |
| 2 | No data were found for 1942. Some data on area dust levels for 1943-1945 and some data on radon levels are available for 1945. | No data were found for 1942. Some data on dose rates for various work locations are available for 1943-1944. More extensive data on dose rates are available for 1945. |
| 4 | No data were found for 1942. Some data on area dust levels are available for 1943-1944. More extensive data on dust levels are available for 1945. | No data were found for 1942. Some data on dose rates for various work locations are available for 1943-1944. More extensive data on dose rates are available for 1945. |

Note: Section 7.0 of this report describes the practical relevance of the data limitations identified in this section with respect to the feasibility of dose reconstructions.

## 6.0 Summary of Radiological Operations Relevant to the Class

The following subsections summarize the radiological operations at the Mallinckrodt facility from 1942 to 1945 and the extent of information available to NIOSH to characterize particular processes and radioactive source materials. The principal source of information for these sections is the Mallinckrodt TBD. This document contains process and source descriptions. It presents available information regarding the identity and quantities of each radionuclide of concern, as well as information describing the process through which the radiation exposures of concern may have occurred and the physical environment in which they may have occurred.

## 6.1 Process Description

Starting in April 1942, the Mallinckrodt Chemical Works began research on uranium refining and processing operations which quickly led to large scale uranium production operations. By July of 1942, approximately 50 days from the beginning of the project, Mallinckrodt was producing almost a ton of uranium dioxide ($UO_2$) per day.

The initial source material for the facility included uranium ores received from various mines and mills. High grade pitchblende ore was first introduced and processed at the facility during 1943-1944. According to the available information, uranium production operations from 1942-1945 were restricted to Plants 1, 2, and 4 of the facility. A summary of the processes in each of these plants is provided below. A more detailed discussion of these processes are discussed in *Fuel for the Atomic Age – Completion Report on St. Louis Area Uranium Processing Operations, 1942-1967*.

Plant 1

Plant 1 conducted laboratory scale developmental work for the operations in Plants 2 and 4. Processes were tested on a pilot scale within Plant 1 prior to the full scale operations in Plants 2 and 4. Research and development work on pitchblende ores (also known as Belgian Congo Ores, which contained high concentrations of uranium and substantial radium content) began in 1944. Related laboratory work occurred in Building 25-2 and Building K1-E contained the pilot plant to test the pitchblende ore extraction methods. Most significant with respect to exposures with potential to deliver substantial internal radiation doses, the processes tested involved batch operations which necessitated manual scooping of uranium products and waste products, which had potential to produce and aerosolize substantial quantities of radioactive dusts. Plant 1 also included the engineering and administrative offices for uranium processing operations at the facility. MED/AEC operations in Plant 1 were terminated after 1945 and transferred to Plant 6.

Plant 2

Plant 2 began uranium refining operations (production of $UO_2$ from ore concentrates that were originally received from other facilities) in April of 1942, and by July 1942, Plant 2 attained a production rate of one ton of $UO_2$ per day. African and Canadian ores were also milled onsite and converted to black oxides. Most significant with respect to exposures with potential to deliver substantial internal radiation doses, the process in Plant 2 involved batch operations which necessitated bulk transfer of the materials from building to building during the refining process. This process, as tested in Plant 1, required manual scooping of uranium products and waste products, which had potential to produce and aerosolize substantial quantities of radioactive dusts. A continuous flow process to replace this manual batch operation was pilot tested in Plant 2 in 1945 but not implemented for production until operations were transferred to Plant 6 in 1945-1946.

To produce $UO_{2,}$ ore concentrates were digested in nitric acid to produce uranyl nitrate. The uranyl nitrate was purified by using an ether extraction process. The uranyl nitrate was then converted to uranium trioxide ($UO_{3)}$ through denitrification and oxidized to $UO_2$ using furnaces. Certain locations of Plant 2 served as a warehouse to store incoming feed materials, outgoing product, and tanks of process liquids. In 1945, an annex to one of the buildings in Plant 2 was constructed to serve as a pilot plant for the continuous extraction process that was to replace the manual batch process. All Plant 2 MED/AEC operations were terminated in 1945-1946 and transferred to Plant 6.

Plant 4

In October 1942, Plant 4 was converted from a lumber sash and door works to a uranium refinery to convert $UO_2$ into uranium tetrafluoride ($UF_4$) and then into uranium metal. In mid-1943, the production of $UF_4$ commenced in Plant 4 using $UO_2$ from Plant 2. The production of $UF_4$ occurred in Building 400 and the conversion of $UF_4$ into uranium metal occurred in Buildings 400 and 401B. Plant 4 operations, similarly to those of Plants 1 and 2, included substantial manual manipulation of radioactive materials with the potential to produce and aerosolize substantial quantities of radioactive dusts.

## 6.2 Radiological Source Materials

The following subsections summarize information on source materials with potential to produce radiological exposures.

### 6.2.1 Uranium Ores

The uranium content of the ores processed by the facility, which came from multiple mines and mills, varied substantially, as did other radiologically significant daughter products. Pitchblende ores contained high levels of Radium-226 (Ra-226) and Thorium-230. Radium-226 (in equilibrium with its progeny) constitutes a significant gamma radiation source and thus produced most of the external whole-body dose received by the workers, while Thorium-234 and Protactinium-234, both beta emitters, would have produced most of the skin and extremity dose. In addition, storage and processing released radon and radioactive dusts, potentially resulting in internal doses to the lung and other tissues due to inhalation. The levels of radon releases would have correlated closely to the radium content of the ore and its derivatives. Because the concentration of radium and other daughters present at any given time in the ore, in the processed uranium, and in processing residue, depended on the concentration of uranium in the ore, the levels of radiation doses received by workers would have depended, in part, on the particular uranium ore being processed at a particular time.

### 6.2.2 Uranium Products

In 1942, there was potential for workers at the facility to have direct contact with uranium in the form of triuranium octaoxide ($U_3O_8$) when mixing it with nitric acid for digestion (MED 1942). When the pitchblende ore began to be used, contact was reduced as much as possible. To minimize personnel exposure, the ore storage room was divided by brick piers into corridors, with each corridor being wide enough to hold stacks of drums four drums wide and two high (MED 1946c). It was thought that this design would eliminate the need for workers to pass between or close to ore during the ore storage and transfer operations. However, due to the blocking of some corridors and the filling of others with a higher quantity of ore drums, workers had to pass close by the ore drums in the crowded corridors (MED 1946c). In addition, workers had to handle the barrels manually throughout this period.

Once the Ra-226 was removed following the digestion step and the vessel(s) had been vented, the gamma dose rates would have been lowered substantially. The radon (which arose from the radium) was no longer an issue from this point forward in processing, except for the presence of radium-bearing residue.

### 6.2.3 Process Residues

African Metals, which supplied the Belgian Congo Ore used by the facility, required that the facility extract and return to it the Ra-226, the Ra-226 progeny, lead and precious metals (AEC 1967; AEC 1949b). Thus, the Mallinckrodt process included steps to extract these materials as a separate residue, called gangue lead cake or GLC.

As much as 100 grams of Ra-226 (approximately 100 curies), contained in the GLC residues, was produced per month at the facility (AEC 1949b). It is also known that quantities of the residues were stored at the site before being transported elsewhere. For example, 200 grams had been transported at one time from the facility to Middlesex (AEC 1949b), meaning that this quantity had been in storage at the Mallinckrodt site and had to be loaded for transport at one time. The residues were stored in drums (FUSRAP 1996). The same storage design and precautions as for the ore were followed for the radium-containing waste (MED 1946c). It is not known, however, how much of the residues were stored at the facility at any given time. We know the quantity of residues that was sent in 1946 to the St. Louis Airport Site (SLAPS) for storage and transportation to other facilities. But we do not know whether previously older residues had been shipped elsewhere.

## 7.0 Evaluation of Feasibility of Dose Reconstruction

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

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 (identified in section 6.0 of this report). If not, NIOSH systematically evaluates the sufficiency of different types of monitoring data, process and source or source term data, which together or individually might assure 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. This approach is specified in the SEC Petition Evaluation Internal Procedures (OCAS-PR-004) available at www.cdc.gov/niosh/ocas.

Section 4.0 includes a summary of NIOSH dose reconstructions relevant to this evaluation. NIOSH is not conducting and has not completed any dose reconstructions for members of the class proposed in this evaluation that provide either maximum or best estimates of the employee's radiation doses. (NIOSH has completed dose reconstructions for some members of the class for whom radiation doses of record were alone sufficient to support an affirmative compensation decision by the Department of Labor.) Therefore, there are no current or completed NIOSH dose reconstructions that demonstrate the feasibility of estimating with sufficient accuracy the potential radiation exposures of the class.

The evaluation that follows examines separately the availability of information necessary for reconstructing internal and external radiation doses of members of the class.

### 7.1 Internal Radiation Doses

The principal source of internal radiation doses for members of the class was radioactive dusts (particulates) aerosolized through processing of radioactive materials and re-aerosolized after settling on surfaces through traffic, housekeeping, and other means of disturbance. These aerosolized dusts could be inhaled, where they would expose the lung and other tissues. Radon progeny, another respirable radiation hazard, was also a source of internal exposure in certain areas of the plants.

The subsections below summarize the extent and limitations of information available for reconstructing the internal doses of members of the class. Most of the information summarized below is provided in greater detail in the TBD on the facility.

### 7.1.1 Urinalysis Information and Available Data

Mallinckrodt uranium processing workers were given a pre-employment physical that included an initial urinalysis and a blood count (MED 1942) and they were given an annual physical that included a urinalysis and a blood count, which is identified as a "follow-up" examination (MED 1942; MCW 1955d; Mason 1958a). However, these urinanalyses do not appear to have included bioassays of any radionuclides; no such urinalysis results are available for the period covered by the evaluation, and there is no evidence that measurements of uranium in the urine were performed during this period. Urinalysis results are available from the routine urinalysis program that began in 1948 and from testing performed retrospectively in 1949, to evaluate acute exposures of concern or potential for injury due to chronic exposure.

### 7.1.2 Information and Available Data Regarding Other Types of Bioassay

A program of breath radon measurement did not begin until June 1945 (MED 1945e; MCW 1946g) for workers who worked in areas where there was a considered potential for radium intake. Breath radon samples were collected by obtaining one-liter samples of exhaled breath after two days of non-exposure, usually on a Monday morning (AEC 1949g; AEC 1950a; MCW 1950g). The samples were measured at the National Bureau of Standards (AEC 1949g) or at New York Operations Office (NYOO) (AEC 1950a; MCW 1955d) by an "automatically recording pulse-counting device" (AEC 1950a). If a sample was over the "tolerance level" of $1 \times 10^{-12}$ Ci/L, then a re-check (repeat sample) was made, immediately (AEC 1949g). The lower limit (of detection) was 0.1 pCi/L and there was confidence in readings of greater than or equal to 0.5 pCi/L (ORAU 1983b). In 1946, it was reported that of 40 workers tested, the maximum level was the tolerance level of $1 \times 10^{-11}$ Ci/L (MCW 1946g). For 1945, few radon breath analyses of employees are available.

Whole body and lung counts appear to have been performed rarely, if at all. Individual whole body and lung count data are not available for the period covered by this evaluation.

### 7.1.3 Airborne Dust Levels

In the early years, measurements of airborne dust concentrations were used as indicators of potential exposure and of the need for changes in processes and equipment (AEC 1950a). Eisenbud (1975) stated that "above all other types of exposure, it was the airborne alpha-emitting dust that was the cause of greatest concern." This hazard was particularly acute in the sampling and crushing of ore and in the mechanical and manual handling of dry uranium salts and oxides (Eisenbud 1975). Mason (1958a) stated that while no regular dust sampling program was in effect at Mallinckrodt during 1943-1947, enough samples were collected to show that concentrations were high by 1958 standards; that concentrations of 50 to 100 times the maximum allowable concentration (MAC) level of 70 dpm/m$^3$ were not uncommon; and that some operations produced concentrations up to 1000 MAC for a few minutes at a time. The high dust levels were of concern to both MED and Mallinckrodt. MED (1944h), in transmitting to Mallinckrodt the results of dust samples taken in June 1944 in the bomb and furnace areas, noted that the results were high and that either ventilation in those areas should be improved or respirator use should be required. Mallinckrodt determined that that dust concentrations around the various crushing, grinding, and packaging operations exceeded the tolerance levels by a factor of 1-300 (MED 1944k). As a result, Mallinckrodt hired a consulting engineering firm to develop a re-design proposal for dust control (MED 1944k).

New processes were implemented from 1944-1946 to reduce high airborne dust levels associated with the green salt unloading, grinding, milling, and blending operations, to perform them under hoods in a continuous sequence, instead of in batch mode, and to use mechanical instead of manual blending. Similarly, ventilation improvements were implemented for bomb loading, jolting, unloading, charge blending and the biscuit chipping, and the green salt blending operation adopted mechanical instead of manual mixing (MED 1944n).

The table below presents the number of air samples taken by MED in Plants 1, 2, and 4 during the period addressed in this evaluation. The samples represent single point-in-time measurements. Most locations are represented by a single sample measurement and NIOSH does not have information to correlate these samples to specific feed material. Nor does NIOSH have sufficient information to correlate these samples to samples from later periods, when monitoring was frequent, although some of the samples taken in 1944 at Plant 4 suggest significantly higher airborne radioactivity existed during this early period, as would be expected due to the process improvements that were subsequently implemented. The utility of these monitoring data is particularly limited because NIOSH does not have information to determine whether these monitoring results represent random, typical, average, or worst conditions, except the general indications, as noted above, that measurements were taken in the locations and processes expected to have the highest exposures.

| Plant | 1942 | 1943 | 1944 | 1945 |
|---|---|---|---|---|
| 1 | No Samples | No Samples | No Samples | 5 samples |
| 2 | No Samples | 8 samples all but one location was a single sample measurement | 14 samples (the most samples in a single location was 4) | 12 Samples |
| 4 | No Samples | No Samples | 26 samples (the most samples in a single location was 4 ) | 6 Samples |

The monitoring data might still have utility for dose reconstructions if NIOSH had access to information on the source terms (the specific quantities and contents of the uranium feedstock) being processed at the facility during the time periods of the dust samplings, and such information on the quantities of the residues as well. However, lacking this source term, residue information, and lacking information to characterize the extent and duration of dust generation associated with manual processes, NIOSH does not have adequate information to estimate reasonably maximum internal radiation doses of members of the class associated with dust exposures, which occurred in Plants 1, 2, and 4.

### 7.1.4 Radon

Radon levels could be substantially elevated in enclosed areas in Plants 1 and 4, where material containing uranium daughter products was stored. It is likely that workers were exposed to short, high level exposures when opening 55 gallon drums of ore, opening storage rooms, and other enclosed equipment containing the ore and residues (ORAU 1989a).

Some early radon measurements occurred in 1945 in Plants 1 and 4, using methods developed at the facility. However, routine air sampling did not begin until 1946, when radon samples were taken once a week in high-radon areas (MCW 1950d). The principal locations which were found in 1946 to be difficult to keep radon concentrations below tolerance levels were the rail cars during unloading of ore drums and in the ore and residue storage area (MED 1946c). In locations affected by the digest vent exhaust and the residue, the radon levels were likely to have varied depending on the stage and timing of processing. A percentage of the radon produced during decay, which would have varied depending on particulars of the ore and processing conditions, would be adsorbed on the surface of the ore particles. When the ore was digested in acid, the adsorbed radon was released and the gamma activity of the ore would drop. When the radium was subsequently precipitated from the acid solution as sludge, the precipitate would adsorb some of the radon, resulting in an increase in gamma activity as the precipitate “aged” (AEC 1947e).

Enclosed spaces in MED/AEC refineries produced radon concentration levels of up to $10^{-8}$ to $10^{-7}$ Ci/L from 1944-1949 (Eisenbud 1975). Improvements in ventilation reduced these exposures but did not generally control them to within the preferred level of $10^{-10}$ Ci/L until 1949.

Most of the information regarding potential radon levels comes from the weekly “M Z” radon reports (MZ was a code for radon) (MCW 1955d; MCW 1947 - 1957). Additional data is shown in the table below (from AEC 1949b, Table 1), which gives typical radon exposures for different areas at the Middlesex facility over the years 1944-1949 (covering the early years of pitchblende use). (The Middlesex facility in New Jersey supplied the Destrehan facility with its uranium ore.) While these exposures are similar to the railcar unloading and ore room operations at the Destrehan facility, these exposure levels do not bound exposure levels for the period covered by this evaluation, because of the different processes at the Destrehan facility discussed above and because even the similar processes were improved substantially at the end of the period covered by this evaluation and subsequently, which would be reflected in the data from Middlesex.

**Middlesex ore storage worker radon exposures, January 1944-January 1949[4] {TC "26Middlesex ore storage worker radon exposures, January 1944–January 1949" \f T \l "8"}**

| Area | Level | | |
|---|---|---|---|
| | **Min** | **Avg** | **Max** |
| Railcar unloading | 200 | | 250 |
| Drying room | 1 | 6.7 | 21.7 |
| Storage area | 0.1 | 0.8 | 2.9 |
| Sampler rooms | 0.1 | 0.2 | 0.5 |
| Crushing area | 0.1 | 0.2 | 0.9 |
| Crusher pit | 0.3 | 0.8 | 1.3 |
| Sampling lab | <0.1 | <0.1 | <0.1 |
| Weigher's booth | <0.1 | <0.1 | <0.1 |

Lacking monitoring data from the relevant period or comparable monitoring data from other facilities, dose reconstructions would require source term information and more detailed process information, including the volumes of internal spaces in the buildings and enclosures where radon would have accumulated, the duration of operations and the storage of materials, etc. As discussed above, NIOSH has not obtained this fundamental source term and process information and cannot determine the quantities, locations, and duration of storage of residues that would have released radon. Hence, NIOSH cannot reasonably estimate even maximum internal radiation doses associated with radon exposures that could have occurred in Plants 1 and 4.

### 7.2 External Radiation Doses

As discussed in Section 6.2.1, the pitchblende ores contained high levels of Ra-226. Ra-226 (in equilibrium with its progeny) constitutes a significant gamma radiation source and thus produced most of the external whole-body dose received by the workers, while Thorium-234 and Protactinium-234, both beta emitters, would have produced most of the skin and extremity dose.

The subsections below summarize the extent and limitations of information available for reconstructing the external doses of members of the class. Most of the information summarized below is provided in greater detail in the TBD.

#### 7.2.1 Film Badge Monitoring

Workers were not individually monitored for external dose prior to December 1945, except for a limited pilot program starting around June of 1945. NIOSH has not obtained any monitoring results from the pilot program.

[4] Radon levels are given in multiples of the radon maximum permissible concentration (MPC) or preferred level of $10^{-10}$ Ci/L.

### 7.2.2 Gamma, Beta, and Nonspecific Beta-Gamma Exposures

Because the gamma radiation dose arose mainly from the radium and its daughters, the dose would have been highest in those areas where the source material had not yet had the radium separated; where radium-bearing residues were most prevalent; and where uranium products were stored for long enough periods of time that the daughters could accumulate again. For the period addressed by this evaluation, these areas were in Plant 1 and more extensively in Plant 2, especially around ore drums and storage areas for the radium-bearing residue, K-65.

There are limited gamma dose rate measurements from 1943 and 1944. As indicated in the TBD, these dose rates are likely to have increased in subsequent years for which there is more dose rate information, due to the increased volume of uranium processed and to the increased use of pitchblende ores.

In 1946, the principal source of significant gamma radiation was said to be the drums of ore as they were stacked in the receiving warehouse (MED 1946c). The gamma dose rate could be as high as 50 mR/hr near stacks of drums of pitchblende ore at 25% concentration and with a radium content of about 100 mg/ton (Eisenbud 1975). A 1958 AEC report documents dose rates of 0.8 to 8.0 mR/hr, with an average of 3.0 mR/hr, as the gamma dose rate at three feet from bulk ore concentrates (AEC 1958, Table XI); these rates are likely to have been associated with domestic ores. The maximum external gamma radiation doses associated with exposure to ores could be estimated for the class, if necessary, by assuming constant exposure to the ore barrel storage locations. Dose rate survey information is available for this area and dose rates could be modeled assuming maximum concentrations of Ra-226. More detail addressing how these radiation doses could be estimated is provided in the TBD in section 7.4.

Gamma dose rates from wastes could have been substantially higher than those for the ore. Dose rates at points adjacent to stacks of drums of radium-bearing residues (precipitates) were as high as 100 mR/hr (~ 300 mg Ra/ton) (Eisenbud 1975, Table 2) and up to 275 mR/hr for direct contact with the drums (MCW 1949g). AEC (1948c) gave the gamma contact dose rate with the (radium-containing) Feinc filtrate residue under equilibrium conditions (conditions resulting in maximum exposures) as over 300 mR/hr. The highest dose rates would have been associated with operations involving manual transfer and manipulation of the waste materials. These included: (1) the various dumping, scooping, and scraping operations in which feed, $UO_2$, $UO_3$, $UF_4$, and dust were handled or crucibles and furnaces were cleaned; (2) the "plowing" (scraping) of the centrifuges; and (3) the scraping of cake off the Feinc filter cloths (this was the pitchblende cake during the pitchblende years). Maximum external gamma radiation doses associated with exposure to residues could be estimated for the class, if necessary, by assuming a maximum dose rate associated with operations involving the Feinc (rotary vacuum filter) in Plant 6. NIOSH has adequate monitoring data for such operations, which would have produced higher gamma dose rates than those occurring in Plants 1, 2, and 4, because of the higher concentration of radium-bearing materials.

Beta doses could have been relatively high in Plants 1, 2 and 4, due to the manual processes in place at the time that would have resulted in greater bodily proximity to sources. High beta dose rates would have been associated with the uranium in its various forms (e.g. uranium and uranium oxide) and two waste concentrates that produced high beta dose rates. First, when ether was used to extract the uranium from uranyl nitrate, Thorium-234 and Protactinium-234m were left in the aqueous phase, also called the aqueous uranium tails (Eisenbud 1975). The second waste concentrate was produced when the aqueous solution was filtered, resulting in a residue (cake) containing the beta emitters. The 1942 measurements of these exposures indicated that the intensity was low (MED 1942) but MED/AEC later found these beta dose rates were significant in some cases in excess of 1000 times the beta activity of natural uranium (AEC 1949a). Maximum external beta doses associated with exposure to residues could be estimated for the class, if necessary, by assuming dose rates associated with the sample analysis operations of residues in the laboratories, which would have been the highest because of proximity and the various material samples handled in the laboratory settings.

More detail addressing how the gamma and beta radiation doses could be estimated is provided in the TBD in section 7.4.

#### 7.2.3 Neutrons

Neutron exposures at the facility were not substantial during the period covered by this evaluation (Sections 5.4.2 of TBD). The ores, residues and processes were not capable of producing substantial neutron exposures. The only potentially substantial source of neutron exposure at the facility would have been neutrons produced by the alpha-neutron reaction in the mixtures of uranium/thorium and fluorine, which occurred after 1954, which is outside the period of this portion of the evaluation. Maximum neutron doses associated with exposure during this period could be estimated by multiplying the measured or reconstructed gamma exposures at the Mallinckrodt facility by the known ratio of neutron to gamma dose for alpha-neutron reactions in fluorine matrices.

### 7.3 Summary of Feasibility Findings

The table below summarizes the results of the feasibility findings for each exposure source.

| Source of Exposure | Maximum Exposure can be determined | Maximum Exposure cannot be determined. |
|---|---|---|
| Internal | | X |
| - Airborne Dust | | X |
| - Radon | | X |
| External | X | |
| - Gamma | X | |
| - Beta | X | |
| Neutron | N/A | |

This report evaluated the feasibility for completing dose reconstructions for workers at the Mallinckrodt Destrehan Street facility, Plants 1, 2, and 4, during the operating years of 1942 through 1945. NIOSH found that the monitoring records, process descriptions, and source term data available are not sufficient to complete dose reconstructions for this class of employees. Furthermore, NIOSH did not identify any groups of employees or locations at the facility during the time frame of the class for which NIOSH could be assured that complete dose reconstructions would be feasible, accounting for all radiation doses that such employees might have received. There is a paucity of information about the locations of specific processes, the movement and storage of materials, the extent of contamination, and of the tasks and routines associated with particular jobs at the facility for the time frame of 1942 to 1945. Moreover, there is information indicating that even employees who worked within the Plants in close proximity to the buildings could have had non-reconstructable exposures, given the pilot plant testing of materials in the Plant 1 alley (Fleishman-Hilliard 1967).

**Note:** The determination by NIOSH that it cannot estimate radiation doses with sufficient accuracy for members of this class does NOT necessarily mean that NIOSH cannot estimate ANY radiation doses with sufficient accuracy for ALL members of this class. In a case in which a member of this class incurred a cancer not included among the 22 specified cancers covered by EEOICPA and hence requires a dose reconstruction (or would otherwise be left without a remedy), it is possible that NIOSH could reconstruct some or all of the radiation doses relevant to the individual's cancer in conformance with 42 CFR Part 82.

## 8.0 Evaluation of Health Endangerment

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. 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 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.

As discussed in section 7.1.3 of this report, NIOSH has determined from the limited air sampling data available that alpha-emitting dust concentrations from 1943-1947 were high by 1958 standards; that concentrations of 50 to 100 times the MAC level of 70 dpm/m$^3$ occurred; and that some operations produced short-term concentrations up to 1000 MAC. As discussed in section 7.1.4, NIOSH has also determined that radon levels at the Mallinckrodt facility could have been high during this early period; monitoring of radon levels during later periods and at another facility that supplied the source material indicate exposures of up to a 1000 times the "preferred level" were likely to have occurred. Based on this information, NIOSH has determined that it is reasonably likely that such exposures to alpha-emitting dust and radon, substantially exceeding safety limits and guidance of the period, may have endangered the health of the Mallinckrodt workers covered by the proposed class definition provided in section 9.0 of this evaluation.

The NIOSH evaluation did not identify any evidence from the petitioners 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 and 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. The evidence reviewed in this evaluation indicates that some workers in the class may have accumulated substantial chronic exposures through repeated, episodic inhalations of radionuclides. Consequently, NIOSH is specifying that health was 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.

## 9.0 Proposed Class Definition

This evaluation defines a single class of employees for which NIOSH cannot estimate radiation doses with sufficient accuracy and whose health may have been endangered by such radiation doses. This class includes employees of DOE or DOE contractors or subcontractors employed by the Uranium Division of Mallinckrodt during the period from 1942 through 1945 and whom were employed for a number of work days aggregating at least 250 work days within these three plants or in combination with work days within the parameters (excluding aggregate work day requirements) established for classes of employees presently included in the SEC. This proposed class definition includes all such employees of DOE or DOE contractors or subcontractors who worked within the three plants, irrespective of job title or job duty.

In consultation with the Division of Energy Employees Occupational Illness Compensation, Department of Labor, NIOSH has determined that Plants 1, 2, and 4 are functionally equivalent to that portion of the Mallinckrodt Destrehan Street facility known as the Uranium Division, and has therefore proposed a class definition that utilizes that designation.

**Note on Continuing Evaluation of SEC Petition No. 12**

This evaluation report does not conclude the NIOSH evaluation of SEC Petition No. 12, qualified on (November 24, 2004), which requested HHS to consider the addition to the SEC of a class of employees including in the entire uranium division at the Mallinckrodt Destrehan Street facility in St. Louis, Missouri from 1942-1957. NIOSH has completed its evaluation concerning the feasibility of dose reconstruction for the period 1946-1957 and has issued SEC Petition Evaluation Report SEC-00012-2.

## 10.0 References

**Note:** The reference document identifier matches the references from the Mallinckrodt TBD


**AEC 1947e**
Atomic Energy Commission (AEC).Visit to Mallinckrodt, St. Louis, Missouri. Memorandum to G. W. Beeler from R. V. Randall, 17 February 1947.

**AEC 1948c**
Atomic Energy Commission (AEC). Mallinckrodt Chemical Works Proposal for Improvement in the Method of Feinc Filtrate Clarification. Memorandum to W. E. Kelley from B. S. Wolf; 24 September 1948.

**AEC 1949a**
Atomic Energy Commission (AEC). Beta Calibration of Zeus. Letter to K. J. Caplan of Mallinckrodt Chemical Works from B. S. Wolf of AEC. 9 March 1949.

**AEC 1949b**
Atomic Energy Commission (AEC). Health Hazards in NYOO Facilities Producing and Processing Uranium. Report by the New York Operations Office Medical Division.18 April 1949.

**AEC 1949g**
Atomic Energy Commission (AEC). Visit to Mallinckrodt Chemical Works, St. Louis, Missouri. Memorandum to Files from H. Blatz. 1 March 1949.

**AEC 1950a**
Atomic Energy Commission (AEC). An Estimate of Cumulative Multiple Exposures to Radioactive Materials, Mallinckrodt Chemical Works, Plants 4 and 6. Report covering July 1942 to October 1949. Mallinckrodt-5; 20 November 1950.

**AEC 1958**
Atomic Energy Commission (AEC). Environmental Hazards Associated with the Milling of Uranium Ore. HASL-40; Revised, 14 November 1958.

**AEC 1967**
Atomic Energy Commission (AEC). Historical Review of the Mallinckrodt Airport Cake. Report (transmitted with cover letter from J. R. Katz, legislative assistant to Missouri Congressman Robert A. Young, to Dr. W. E. Mott, Director, Division of Environmental Control Technology, Department of Energy, 26 July 1978). 1967.

**Eisenbud 1975**
Eisenbud M. Early Occupational Exposure Experience with Uranium Processing. In: Occupational Health Experience with Uranium. Proceedings of a United States Atomic Energy Commission conference. Arlington, Virginia: ERDA-93; 1975: 9-24.

**Fleishman-Hilliard 1967**
Fleishman-Hilliard, Inc. Fuel for the Atomic Age. Completion report on St. Louis area uranium processing operations, prepared for Mallinckrodt Chemical Works to document performance under AEC Contract No. W-14-108-Eng-8. 30 September 1967.

**FUSRAP 1996**
Formerly Utilized Sites Remedial Action Program (FUSRAP), US Department of Energy. Management Action Process Document for the St. Louis, Missouri, FUSRAP Sites. Draft; March 1996.

**MCW 1946g**
Mallinckrodt Chemical Works (MCW). No subject. Letter to W. D. Fleming of the Manhattan Engineer District from S. H. Anonsen of Mallinckrodt. 9 November 1946.

**MCW 1949g**
Mallinckrodt Chemical Works (MCW). No subject. Letter to M. Eisenbud of AEC from K. J. Caplan of Mallinckrodt Chemical Works. 6 May 1949.

**MCW 1950d**
Mallinckrodt Chemical Works (MCW). Health Physics Program for Plant Six and Plant Four. Letter to J. J. Koenig of the Atomic Energy Commission from K. J. Caplan of MCW. 14 April 1950.

**MCW 1950g**
Mallinckrodt Chemical Works (MCW). No subject. Letter to H. I. Blatz of AEC from M. G. Mason of Mallinckrodt. 20 April 1950.

**MCW 1955d**
Mallinckrodt Chemical Works (MCW). Mallinckrodt Chemical Works Health Program: Policies, Status, and Summary. Report by M. G. Mason of Mallinckrodt. 21 February 1955.

**MCW 1947-1957**
Mallinckrodt Chemical Works (MCW). M Z Reports. Periodic reports of radon measurements. 1947-1957.

**MED 1942**
Manhattan Engineer District (MED). Supplemental Report To Complete Preliminary Survey of Plants Engaged in Production of Materials. Report by H. L. Friedell of the Corps of Engineers (MED). 23 December 1942.

**MED 1944h**
Manhattan Engineer District (MED). No subject. Letter to H. E. Thayer of Mallinckrodt Chemical Works from R. A. Tybout of MED. 14 July 1944.

**MED 1944k**
Manhattan Engineer District (MED). Report of Visit to Mallinckrodt Chemical Company, 17 and 18 July 1944. Memorandum to the Madison Square Area Engineer from R. A. Tybout. 22 July 1944.

**MED 1944n**
Manhattan Engineer District (MED). Visit to Mallinckrodt Chemical Works -- 6 September 1944. Memorandum to the New York Area Engineer from R. A. Tybout. 8 September 1944.

**MED 1945e**
Manhattan Engineer District (MED). No subject. Letter to S. H. Anonsen of Mallinckrodt Chemical Works from B. J. Mears of MED. 9 July 1945.

**MED 1946c**
Manhattan Engineer District (MED). No subject. Letter to H. E. Thayer of Mallinckrodt Chemical Works from W. F. Bale of MED. 18 November 1946.

**Mason 1958a**
Mason MG. A Summary of Fifteen Years of Experience with Dust Problems in the Refining and Fabrication of Uranium. In: Symposium on Occupational Health Experience and Practices in the Uranium Industry. Proceedings of a United States Atomic Energy Commission conference. New York City: United States Atomic Energy Commission; HASL-58; 1958: 3-9.

**ORAU 1983b**
Oak Ridge Associated Universities (ORAU). Interview with John Harley from NYOO's HASL Concerning Radiation Monitoring Done at HASL. Memorandum to D. Cragle, D. Robie, and W. Tankersley from E. Dupree. 25 March 1983.

**ORAU 1989a**
Oak Ridge Associated Universities (ORAU). Mallinckrodt Chemical Works: Radon Dose Assessment. Memorandum to MCW File from J. N. Ingle. 31 October 1989.

**Attachment 1**

**Mallinckrodt Documents and Reports**
**From Site Research Database**

Mallinckrodt Notes
Mallinckrodt Radon Sampling Procedures
Mallinckrodt Uranium Processing Workers Mortality Report 1998
Mallinckrodt Proposal for Radon Dose Assessment 1998
Estimate of Cumulative Multiple Exposures MCW 1942-1949
MCW - Contract Mods with UO2 Production Rates (w-7405-Eng-19) - 1946
2.0 Site Description and History Close Out Report for FUSRAP
Mallinckrodt Workplace Data Contamination Survey 1959
MCW - Activity Levels, Final Radioactive Survey at Destrehan 1961
MCW AEC - NRL Plant Inspections 1958-1996
MCW - Ionization Chamber Calibration Curve 1948
MCW - Codes for Radioactive Material Identification 1953-1955
MCW - Columbium - Tantalum Plant Characterization on Plant 1994
MCW - Contaminated Material Incineration 1959
MCW - Control of Radiological Hazards during Uranium Processing 1948
MCW - C-T Plant Environmental Information Document 1985
MCW - C - T Preliminary Radiological Investigation (PRI) Final Report - 1993
MCW - Dust Collector Filter Selection Decision Basis 1948-1950
MCW - Environmental Analysis Report 1985
MCW - Event Chronology for Rill Cotter Incident - 1978
MCW - External Radiation Monitoring Program 1998
MCW - Facility Radiological Inspections and Investigations 1993-1994, 1976
MCW - Final Results of East Pile and HISS Spoil Piles
MCW - General Information
MCW - Health and Safety Program Developments 1948
MCW - Health Correction Johns at the Work Site 1948
Health Hazards in NYOO Facilities Producing & Processing Uranium
MCW - Internal and External Radiological Monitoring Data 1958-1961
MCW - Latty Ave. Site Report on Results of Radiological Survey 1977
Information on FUSRAP and Surplus Facility Sites in Missouri
MCW - Mallinckrodt Chemical Company Destrehan St. Plant
MCW - Mallinckrodt Chemical Works MZ Report
MCW - Medical Data Reinstated to Radiological Exposures 1950
MCW - Monthly Report of Field Activities Sept 1950
MCW - New York OPS Office Monthly Report of Field Activities
MCW - NRC Inspections 1996, 1985-1986, 1978, 1979
MCW - Occupational Exposure to Airborne Containments 1953
MCW - Plant 4 Dust Control Letter - 1949
MCW - Plant Changes to Adjust to Request for Increased Slang Grinding Capacity
MCW - Plant Expansion to Increase Metal Plant Capacity 1952-1954
MCW - Plant Operations & Controls for Radioactive Materials
MCW - Rad. Contamination January 1959

MCW - Radiation Exposure Conference Notes & Comments 1950
MCW - Radiological Characterization on Data Set Volume 3 1998
MCW - Radiological Characterization on Data Set Volume 4 1998
MCW - Radiological Characterization on Data Set Volume 5 1998
MCW - Radiological Characterization Data Set Volume 1 1998
MCW - Radiological Characterization on Data Set Volume 2 1998
MCW - Radiological Hazards & Controls for Uranium Operations
MCW - Radon Progeny Measurements for 4088 4Q87, 2Q89,3Q90, & 4Q90
MCW - Source Material Licensing - 1960-1961
MCW - Source Material Licensing - 1961 & Environmental Assessment
MCW - TLD Reports, Radon Reports Partial License Reports Radiological Surveys
MCW - Urinalysis and Radon Analysis Program Basis 1949 - 1950 Surveys
MCW - Whole Body Exposures for Selected Personnel - 1981 - 1985
MCW - and Weldon Springs Possible Use of Quarry for Contaminated Debris Disposal
United Nuclear Corporation - Mallinckrodt
MCW - Plant Drawings and Maps - 1946 - 1955
Documents Associated With Employees Exposure at MCW
Dust Study of the New K-65 Ledoux Laboratory Installation
Film Badge Data February Wage 1966
Film Badge Program
Employee Job History Sheet
Information on X-ray Film & Procedure
Monitoring Results for Donald L. Harrison
Autopsy Report on OWEN KERSNER
Radiation Exposure of Plant 6 Employees
Radiological Limits for Plant 6 and Other Locations
General Information about Product
This document is a duplicate of another document - Refer to 010002059 for entire document
Mallinckrodt - Fuel for the Atomic Age - Report on St. Louis - Area Uranium Processing Operations, 1942 - 1967
Historical Review of the Mallinckrodt Airport Cake
External Radiation Exposure and Mortality in a Cohort of Uranium Processing Workers
Radiological Survey of the Mallinckrodt Chemical Works, St. Louis
Observation of the Electrolysis of UO2 at Mallinckrodt Chemical Works, Weldon Spring, Missouri from June 1, 1966, to October 7, 1966
Disposal of Destrehan Street Facilities and Restoration of Site
Lowman Mill and Disposal Site, Boise County, Idaho
SLDS Fact Sheet
Sales of Residues at the Airport Site
Radon Breath Analysis (1945 - 1947)
Breathe Samples at MCW (1945, 1946, and 1947)
Utter Principle Potential Radioactive Hazards at Mallinckrodt
X-Ray Examination Frequency Change (1946)
Plant 6 Air Samples (1946)
Mallinckrodt Film Badge Results (1945, 1946, and 1947)
Radon Breath Samples (1946 & 1947)

Film Badges Results (1946 & 1947)
Air Sampling Data - Feb - June 1944
Film Badge Data and Radiation Measurements at Mallinckrodt (1944)
Film Badge Reports (1945)
Uranium Dust in Air
Dust Samples
Dust Samples
Dust Samples
Various Reports on Mallinckrodt Radiation Hazards (1944)
Progress Report of the Special Materials Division of Medical
Medical Programs in Report at the Mallinckrodt Project
Film Badge Results (1945)
Air Samples at Mallinckrodt 1945
Uranium Refining Process
Toxicology of Thorium
Film Badge Results Aug 18 - Aug 25, 1947
Film Badge Results Aug 4 - Aug 11, 1947
Film Badge Date July 28 to August 4, 1947
Film Badge Date June 2 to July, 1947
Film Badge Date Dec 30, 1946 to June 9, 1947
Radiation Injuries from Uranium
Extractions of Uranium Ore from Domestic Uranium Ore Concentrations
Radon Breath Samples
Film Badge Analysis May 27, 1946 - Sept 2, 1946
Mallinckrodt Film Badge Results May 20-27, 1946
Mallinckrodt Film Badge Results April 22- May 18, 1946
Mallinckrodt Film Badge Results Feb 18 - March 16, 1946
Mallinckrodt Film Badge Results March 18 – 25, 1949
Mallinckrodt Breath Sample Reports Various Dates 1945 - 1949
NNES - Vol. 112B Listing of Papers on Processing Uranium Products
Letter on Beta Effects to Skin
Tabulation of Film Results from Badges Worn Aug 18 – 25, 1947
Tabulation of Film Results from Badges Worn May 19 – 26, 1947
Tabulation of Film Results from Badges Worn May 26 - June 2, 1947
Tabulation of Film Results from Badges Worn June 2-9, 1947
Tabulation of Film Results from Badges Worn June 9-16, 1947
Tabulation of Film Results from Badges Worn June 16 - 23, 1947
Tabulation of Film Results from Badges Worn June 23 - 30, 1947
Tabulation of Film Results from Badges Worn June 30 - July 7, 1947
Tabulation of Film Results from Badges Worn July 7 - 14, 1947
Tabulation of Film Results from Badges Worn July 14 - 21, 1947
Tabulation of Film Results from Badges Worn July 21 - 28, 1948
Tabulation of Film Results from Badges Worn July 28 - Aug 4, 1947
Tabulation of Film Results from Badges Worn Aug. 4 - 11, 1947
MCW Dosimetry results 8/25/47 - 10/13/47
Weekly dose results for MCW 4/1946 to 4/1947

Weekly dose results for MCW 10-13-47 to 12-29-47
Dust Study for Shotgun Lab
Code used for Materials at MCW
Radon & Dust Studies 1948 to 1953
Work Permits for warehouse operations
Dust Study at Plant 6
Housekeeping Memo
Dust Study Report Plant 6
Comments on Plant 4 Operations 1951
K-65 sapling lab conditions report
Report -Pollution of Plant 6 Yard
Memo on shipping empty drums
Radon Dose Assessment
The relationship between breath radon measurements & skeletal radium burdens
Information from Mont Mason & other site specific information
Interim Report on Film Badge Exposures in Shotgun Laboratory
Film Badge Results
Various Process Dust Studies 1961
Radioactive Airborne Dust Study of Sampling of Feed Materials for Oil Analysis
Radioactive Dust Concentrations U-Con Grinding in the Shotgun Laboratory
Dust Study Information
Documentation on Reconciling MCW Film Badge Data
Hand Loading of Raw Ore into Secondary Elevator
Radon in Ore Room
Health Inspection of Plant 6, 10/17/55
Scalehouse Sample Room Study
Crucible Burn-Out Hood Stack at Plant 4
Correction of Beta Radiation at Plant 4 Recasting Operations, August 1949
Report-Dust Concentrations in Kinney Pump Discharge, August 1949
Proper Use of Dust Collecting System on Vacuum Furnace
Use of Old Crucibles in the Recast Furnace
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