SEC Petition Evaluation Report
Petition SEC-00079

Report Rev #: Addendum 2 Report Submittal Date: June 3, 2008

Subject Expert(s):	James Mahathy
Site Expert(s):	N/A

Petitioner Administrative Summary			
Petition Under Evaluation			
Petition #	Petition Type	Petition A Receipt Date	DOE/AWE Facility Name
SEC-00079	83.14	November 28, 2006	Dow Chemical Company (Madison Site)

Proposed Class Definition

All Atomic Weapons Employer employees who were monitored, or should have been monitored, for exposure to thorium radionuclides while working at the Dow Chemical Company site in Madison, Illinois, for a number of work days aggregating at least 250 work days from January 1, 1957 through December 31, 1960, or in combination with 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
NONE			

Related Evaluation Report Information	
Report Title	DOE/AWE Facility Name
SEC Petition Evaluation Report, SEC-00079	Dow (Madison Site)
SEC Petition Evaluation Report, SEC-00079, Addendum 1	Dow (Madison Site)

Peer Review Completed By:	[Signature on file] *L. Rutherford*	06/03/2008 Date
SEC Petition Evaluation Reviewed By:	[Signature on file] *J. W. Neton*	06/03/2008 Date
SEC Evaluation Approved By:	[Signature on file] *Larry Elliott*	06/03/2008 Date

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Addendum 2 to Dow Madison (SEC-00079) Special Exposure Cohort Evaluation Report

<u>NOTE</u>: This Addendum only addresses those sections in the Dow Madison Evaluation Report that require discussion. Therefore, the section numbering is not contiguous.

<u>ATTRIBUTION AND ANNOTATION</u>: This is a single-author document. All conclusions drawn from the data presented in this evaluation were made by the ORAU Team Lead Technical Evaluator: James Mahathy; Oak Ridge Associated Universities. These conclusions were peer-reviewed by the individuals listed on the cover page. The rationales for all conclusions in this document are explained in the associated text.

NIOSH presented a Special Exposure Cohort (SEC) evaluation report (NIOSH, 2007) about the Dow Chemical Company, Madison, Illinois (Dow Madison) to the Presidential Advisory Board on Radiation and Worker Health during the Advisory Board's regular meeting on May 3, 2007. The report evaluated the feasibilities of reconstructing radiation doses arising from the use of uranium and thorium during the Atomic Weapons Employer (AWE) operations period from January 1, 1957 through December 31, 1960 and from exposure to residual uranium from January 1, 1961 through December 31, 1998. The feasibility of reconstructing doses received from exposure to residual thorium was not considered because the Department of Energy (DOE) characterized thorium use during the AWE operations period as commercial. Commercial sources of radiation exposure at AWE sites must be considered in the assessment of dose received during AWE operational periods. However, non-AEC thorium doses received during the site's residual radiation period are not included in the assessment of site doses. NIOSH stated in the evaluation report that doses received from exposures to uranium could be reconstructed during both the operations and residual periods, but exposure to thorium, although used commercially, could not be accurately reconstructed during the AWE operations period and recommended adding a class on this basis. On May 23, 2007, the Advisory Board recommended to the Secretary, Department of Health and Human Services that Dow Madison be added as a class to the SEC. On June 22, 2007, the Secretary sent letters to the House and Senate specifying that Dow Madison be added to the SEC.

In January, 2008, the DOE notified the Department of Labor (DOL) and NIOSH that after additional research, DOE had concluded that Dow Madison did use thorium in AWE operations. DOE stated that in 1957 and 1958 Dow Madison supplied the Atomic Energy Commission (AEC) (via the Mallinckrodt site) with Mg-Th plates and sheets, and that during this time period, these types of plates and sheets were used in atomic weapons (DOE, 2008). The DOE concluded that, for the years 1957-58: (1) Dow Madison probably produced material for use by the AEC; (2) the material emitted radiation; (3) the material could have been used in the production of an atomic weapon; and (4) Dow Madison's work with Mg-Th plates and sheets is, therefore, a covered AWE operation (DOE, 2008). Since the topic was not addressed in the first Evaluation Report, NIOSH evaluated the feasibility of reconstructing doses from potential exposures to residual thorium contamination. The NIOSH evaluation is presented in this addendum.

Petition Evaluation Report Summary

NIOSH-Proposed Class Definition

NIOSH finds that potential radiation doses received from exposure to residual thorium at Dow Madison from January 1, 1961 through October 31, 2006 can be reconstructed with sufficient accuracy. No changes to the SEC class definition are recommended by NIOSH. This addendum will be provided to the DOL to assist it in implementing the current class definition.

Feasibility of Dose Reconstruction

NIOSH possesses sufficient information, which includes sufficient personnel and workplace monitoring data and radiological source term information to allow NIOSH to estimate the potential total internal and external exposures during the residual radiation period at Dow Madison

4.1 Operations Description

Uranium operations are not applicable to this addendum and are not discussed herein. Before evaluating exposure to residual thorium, Dow Madison thorium operations conducted during the AWE period will be briefly reviewed.

Dow Madison manufactured magnesium alloys that also contained thorium. Dow Madison used one large building complex with separate building numbers assigned to portions of the building (i.e., all buildings were under the same roof structure). The alloying processes used for manufacturing the Mg-Th alloys were documented (AEC, 1960a; Lowery, 1962, Nussbaumer, 1962). Thorium was added to the magnesium melt in the Melt Room at the rate of a 3% to 4% mixture and then the Mg-Th alloy was poured in the Pump-Off area (next to the Melt Room). The production area in the Melt Room building consisted of a work bench, an instrument panel, six crucibles, and one mold. The ceiling in the production area was 65-feet high. The room contained three 20-foot exhaust fans. Ancillary mechanical and finishing operations were conducted in buildings adjacent to the Melt Room building. These operations included the grinding, filing, buffing, and milling of alloy, and the collection and drumming of dusts that resulted from the other operations.

Slag and sludge remaining in the crucible was re-melted and the process was repeated. Sludge remaining after the second melting contained up to 50% thorium. The sludge was broken into pieces and re-melted. After a third pouring, the remaining sludge, containing up to 8 % thorium was transported to the waste yard, later known as the 40-acre CONALCO site. Dow Chemical made some attempts to recover thorium stored in the waste yard by grinding the sludge. According to an AEC compliance inspection report, Dow segregated the sludge for possible future thorium recovery (AEC, 1960b); however, NIOSH has no documentation confirming that recovery occurred. An AEC inspection report states that alloy scrap was also stored (but segregated) at various points throughout the Melt Room building (AEC, 1960a). This statement is consistent with statements in the claimant-supplied affidavits (Kusmierczak, 2007).

Mg-Th scrap was recycled at least once through the melting/alloying process. There would have been little potential for surface or airborne contamination from the stored scrap, although there was potential for some oxidation on the material surface and subsequent entrainment of the oxide. Remaining waste was buried in the waste yard.

AEC license documentation (AEC, 1963; AEC, 1965) limited the authorized quantity of thorium at any one time to no more than 111,000 pounds; however, this amount was the maximum allowed for Midland, Bay City and Madison in total. Mg-Th production runs used from 4,000 to 30,000 lbs. of alloy (AEC, 1960a) with the highest thorium concentration being 4% (equivalent to 1,200 lbs. for a 30,000 lb. run). This information on quantities is useful in determining waste source terms arising from the commercial operations from 1961 onward. According to Dow source material licensing documents, film badges were to be used for some workers and those services were contracted to Health Physics Services; however, NIOSH has not located that data.

Dow continued to make Mg alloys for commercial purposes (including some with thorium) from 1961 through 1969. Dow Chemical sold the Dow Madison plant and the right-to-use patent to Consolidated Aluminum (CONALCO) in 1969. CONALCO received by-product license STB-1097 for thorium. As late as 1972, Dow continued to send between 300 and 500 pounds per month of thorium-containing alloy waste from their Bay City and Midland operations to Madison for disposal (Dow, 1972).

In the late 1970s, thorium-bearing slag arising from commercial operations was buried at the waste yard (Baker, 1992). By the early 1980s, CONALCO stopped putting waste materials in the yard (Mura, 1986). CONALCO produced commercial thorium alloy and shipped thorium wastes off-site to a commercial radioactive disposal site in Barnwell, South Carolina. However, thorium wastes were stored in an on-site area other than the 40-acre CONALCO yard.

In 1982, CONALCO had a radiation safety plan as part of a source material licensing package. According to source material licensing documents, film badges were to be used for some workers and those services were contracted to R. S. Landauer. CONALCO sold the plant to Spectrulite Consortium in 1986. CONALCO assumed responsibility for the 40-acre thorium waste yard, but Spectrulite assumed responsibility for thorium production (Mura, 1986). Spectrulite Consortium filed for bankruptcy in 2003; Magnesium-Elektron bought the remaining inventory and assets but production operations were discontinued. Because the work discussed above was commercial, it is not considered in this evaluation.

NIOSH reviewed documented waste and clean-up operations conducted during the residual period to assess the potential for thorium exposures. CONALCO produced commercial thorium alloy and shipped thorium wastes off-site to a commercial radioactive disposal site in Barnwell, South Carolina. However, some amount of thorium scum that formed on molten metals was stored in an on-site area other than the 40-acre CONALCO yard.

Staff at the Oak Ridge National Laboratory (ORNL) performed a radiological survey at the Dow Madison site in March 1989 (ORNL, 1990). Among the data published in the report are surface smears and dust sample results for samples taken in Building 6 where thorium processing was performed. Smear results revealed concentrations above the DOE regulatory limit for Th-232 (1000 dpm/100 cm^2) in dust sampled from overhead beams at the south end of Building 6 (ORNL, 1990).

The maximum surface contamination of thorium in dust was measured at 1,730 dpm/cm^2 (7.8 pCi/g Th-232), or 1.7 times the average surface contamination guideline limit of 1000 dpm.

In 1992, the Madison Site was added to the FUSRAP list of sites slated for clean-up. The FUSRAP site was within a limited area of an active facility. The plant was in heavy production, extruding aluminum and magnesium metal. Because clean-up was ultimately necessary, the operator worked with the U.S. Army Corps of Engineers (USACE) to identify an available timeframe for clean-up. It was the intent of the facility owner and the USACE that production operations were not to be disrupted during clean-up and that safety of maintenance and production personnel continued to be protected (USACE, 1999).

In 1992, 90,000 cubic yards of soil were removed by firms under contract to CONALCO and Dow Chemical which had retained some of the responsibility for clean-up of the slag. Approximately 1,000 railcars of radioactive waste were sent to commercial disposal sites. CONALCO's radioactive materials license for the 40-acre waste yard was terminated in January 1993. Environmental Restoration Group (Colorado) provided environmental and health physics support during the 1992-1993 clean-up (Baker, 1992). CONALCO reported that the 40-acre waste yard contained 3.3E+6 pounds of total alloy waste containing 1.3E+5 pounds of thorium (NRC, 1986).

Soil containing Th-232 was removed by Spectrulite during the period January - July 1998 (Huber, 1998). Wastes removed in 1998 originated from CONALCO commercial operations. In 1999, the U.S. Army Corps of Engineers (USACE) developed a characterization report for the Madison Site (USACE, 1999, USACE, 2000). Samples were taken to validate existing site data, define site contamination, and update the estimate of associated risk. The Characterization Report confirmed the presence of contamination in the dust on overhead hard-to-reach surfaces; no contamination measured on floors and equipment exceeded release criteria (USACE, 2001). The final clean-up remedy was outlined in the final Record of Decision released in early June 1999. In late June 1999, the USACE deployed its contractor to the Madison site for decontamination of Building 6. By mid-July, independent surveys confirmed that the USACE had successfully decontaminated the site (USACE, 2001). Forty cubic yards of contaminated dust and materials were sent to a licensed, out-of-state facility for disposal. Having completed site remediation, the USACE initiated site closeout to successfully remove the site from the list of active FUSRAP sites. However, additional surveys conducted by Pangea Group in 2002 in Buildings 4, 5, 6, 7, and 8 revealed levels of Th-232 sufficient to warrant clean-up (Pangea, 2005). Some thorium contamination was not removed until October, 2006 (by Pangea Group) (Cushman, 2008). Potential exposures resulting from clean-up operations were considered as part of this addendum, but consideration was only given to the amount of waste materials resulting from AWE operations.

4.3 Time Period Associated with Radiological Operations

DOE had defined the residual period to be from January 1, 1961 through December 31, 1998. However, NIOSH has obtained documentation that demonstrates that contamination attributable to AEC-covered uranium and thorium operations was removed in 2006 (Cushman, 2008). Therefore, NIOSH has initiated a revision to the *Report on Residual Radioactive and Beryllium Contamination at Atomic Weapons Employer Facilities and Beryllium Vendor Facilities* (NIOSH, 2006) to extend the covered residual period through October 31, 2006.

4.4 Site Locations Associated with Radiological Operations

NIOSH has found information to suggest that thorium operations were not limited to a single building. Further, NIOSH has documented that slag and sludge were buried in the waste yard. Therefore, NIOSH has concluded that exposure to residual thorium was possible in all areas of the Dow Madison site.

4.5 Job Descriptions Affected by Radiological Operations

NIOSH has not obtained any additional documentation that can be used to restrict the class description to specific workers, or documentation that can be used to assign workers to particular job categories. Therefore, it is still not possible to use job descriptions to define the class.

5.0 Summary of Available Monitoring Data for the Proposed Class

NIOSH has not obtained additional personal or area monitoring data for the AWE operations period since the first ER Addendum was published in August, 2007. However, NIOSH has identified documents detailing material licenses and information on clean-up activities conducted at the Dow Madison Site (Baker, 1992; Huber, 1998; USACE, 1999; USACE, 2000; USACE, 2001; Pangea, 2005; Cushman, 2008).

NIOSH document capture activities are listed in Attachment 1.

5.1 Internal Personnel Monitoring Data

NIOSH does not have access to any documents that contain personnel bioassay monitoring data for Dow Madison site employees.

5.2 External Personnel Monitoring Data

NIOSH has obtained film badge results for workers at the Dow Chemical Bay City site who were involved in similar operations. However, no film badge results have been obtained by NIOSH for Dow Madison workers, neither during the AWE operations period nor the residual radiation period.

5.3 Workplace Monitoring Data

NIOSH has not identified any area air sampling data obtained during the residual radiation period at Dow Madison except for results obtained during a final clean-up of the site conducted in 2006 (Cushman, 2008). NIOSH also has access to breathing zone and general area air samples collected from 1957 through 1959 (Hoyle, 1957; Dow, 1959; Shrader, 1959) though some of these were obtained at Madison and some at Midland. NIOSH has access to results of thoron monitoring (Shrader, 1959) conducted at Dow Madison in 1959 during operations that used HK-31, (the alloy containing the highest percentage of thorium).

NIOSH has obtained dose rate data obtained by Dow Chemical in the AWE operations period (Silverstein, 1957; Levy, 1957) and from monitoring conducted during the residual radiation period in 1981 (Stein, 1982).

5.4 Radiological Source Term Data

In the Dow Madison Evaluation Report, NIOSH determined that the source term for the AWE period included Th-232 with in-growth of thorium daughters.

6.1 Feasibility of Estimating Internal Exposures

Internal exposures to thorium during the residual radiation period would have resulted from potential corrosion of stored material, re-suspension of dust, scrap handling, scrap cutting, and potential loss of containment of disposed materials. In order to reconstruct internal doses with sufficient accuracy, NIOSH must have access to worker bioassay data, breathing zone and/or area air monitoring data or have accurate information that can be used to define the source term and its activity. No personnel bioassay monitoring results for thorium have been located by NIOSH. Workplace thorium air monitoring results are available for the AWE period and for 2006.

NIOSH has determined that there is sufficient documentation on the processes and controls used at Dow Madison to create a bounding estimate of the concentration of thorium in air on January 1, 1961, the start of the residual radiation period. NIOSH considered the potential exposure arising from residual operations within buildings, residual operations in the waste yard, and release of thorium buried in the waste yard. However, workers would not have been exposed to building and waste yard intakes at the same time.

Potential annual inhalation intakes of thorium and thorium daughters for the January 1, 1961 through October 31, 2006 residual period can be bounded using air monitoring data obtained from 1957 through 1960 and data obtained at Dow Madison in 2006. In order to derive the intake associated with residual activities conducted within buildings, NIOSH used general air sampling results obtained during the AWE operations period from 1957 through 1959 (Hoyle, 1957; Dow, 1959; Shrader, 1959). Process and breathing zone samples were excluded, the rationale being that general area air samples collected during operations would represent contributions from both re-suspension of surface contamination and dispersion of process releases and, as such, would bound the contribution from re-suspension of surface activity alone. Ingestion intakes can be bounded using *Estimation of Ingestion Intakes* (NIOSH, 2004). Bounding analyses for thorium are presented in Attachment 2.

The intake of thoron on January 1, 1961 can also be bounded using thoron monitoring results obtained in 1959 (Shrader, 1959); this analysis is also presented in Attachment 2.

Internal doses received from potential exposures to thorium and thoron can be bounded based on the available information on the Dow Madison alloy process, and available workplace monitoring results. The methodology to reconstruct internal doses is presented in Attachment 2.

6.2 Feasibility of Estimating External Exposures

External doses received from potential exposures to thorium can be bounded; the analysis of available data and bounding methodology are presented in Attachment 2.

7.0 Summary of Feasibility Findings for Petition SEC-00079

This addendum to the Dow Madison Evaluation Report evaluates the feasibility for estimating the dose, with sufficient accuracy, for all AWE employees who worked at the Dow Chemical Company site in Madison, Illinois during the residual period from January 1, 1961 through October 31, 2006. NIOSH determined that it has sufficient source term information, workplace monitoring data for thorium radionuclides, and process descriptions to allow adequate bounding of the total potential AEC-related internal and external exposures at the facility during this time period. Consequently, NIOSH finds that it is feasible to estimate with sufficient accuracy the radiation doses resulting from internal and external thorium exposures received by members of this class of employees.

With the data currently available to NIOSH, it is feasible to reconstruct with sufficient accuracy the external and internal doses resulting from exposure to uranium metal during the Dow Madison AWE operational period (January 1, 1957 through December 31, 1960). NIOSH also considers adequate reconstruction of medical dose for Dow Madison workers to be feasible for the AWE operational period.

NIOSH has documented herein that it can complete the dose reconstructions related to this addendum, (i.e., doses that resulted from exposure to residual thorium from January 1, 1961 through October 31, 2006). The basis of this finding is specified in this report, which demonstrates that NIOSH does have access to sufficient information to estimate with sufficient accuracy 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. Members of this class at the Dow Chemical Company site in Madison, Illinois, may have received unmonitored internal and external radiological exposures from AEC-related thorium radionuclides. NIOSH possesses sufficient information, which includes sufficient personnel and workplace monitoring data and radiological source term information to allow NIOSH to estimate the potential total internal and external exposures to which the proposed class may have been exposed.

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10.0 References

AEC, 1960a, *Compliance Inspection Report: Dow Chemical Co. Site, Madison, Illinois;* U. S. Atomic Energy Commission; August 4, 1960; SRDB Ref ID: 29268

AEC, 1960b, *Compliance Inspection Report: Dow Chemical Co. Site, Madison, Illinois;* U. S. Atomic Energy Commission; November 30, 1960; SRDB Ref ID: 29604

AEC, 1963, Memo from Donald Nussbaumer to W. Otis Heath, Atomic Energy Agency, May 6, 1963; SRDB Ref ID: 29636

AEC, 1965, *AEC Material License for the Dow Chemical Company*, Midland, Michigan, Atomic Energy Agency, March, 1965; SRDB Ref ID: 29673

Baker, 1992, Madison Site Cleanup, Final Report, prepared by Ken Baker, Environmental Restoration Group, December, 1992; SRDB Ref ID: 43582.

Cushman, 2008, Email concerning Madison Site, Matt Cushman, Pangea Group, March 5, 2008; SRDB Ref ID: 41940.

DOE, 2008, Letter from Department of Energy to Department of Labor, January 8, 2008; SECIS SRDB Document ID: 105199

Dow, 1959, *Annual Industrial Hygiene Summary May 1959*, D. J. Levy and H. R. Hoyle; Dow Chemical Corporation, July 27, 1959; SRDB Ref ID 39912

Dow, 1972, Partial letter from Dow Chemical Company to Robert Layfield (AEC), Dow Chemical Company, Midland, Michigan, July 28, 1972; SRDB Ref ID: 29702

Baker, 1992, *Madison Site Cleanup Final Report*, K. R. Baker for Environmental Restoration Group, Albuquerque, New Mexico for the State of Illinois, Department of Nuclear Safety; December 1992; SRDB Ref ID: 43582

Hoyle, 1957, *Thorium Handling, Alpha Counters and Sludge Recovery Hazards*, H. R. Hoyle; Dow Chemical Corporation; December 20, 1957; SRDB Ref ID 39998

Huber, 1998, Uniform low-level radioactive waste manifests and other documents, Stan A. Huber and Associates, 1998; SRDB Ref ID: 41934

Kusmierczak, 2007, Affidavits of former Dow Madison workers regarding thorium, J. Joseph Kusmierczak, Simmons Cooper, LLC, April 16, 2007; SRDB Ref ID: 39868

Levy, 1957, Memo from D. J. Levy, Dow Chemical Company, Madison, IL, March 8, 1957; SRDB Ref ID: 39977

Lowery 1962, *Radiation Hazards in Arc Melting Thorium*, Report of Investigations 5969, R. R. Lowery, Department of the Interior, 1962; SRDB Ref ID: 40074

Mura, 1986, Memo and attachments from William Mura (CONALCO) to Bruce Mallet (NRC), Consolidated Aluminum Company, August 21, 1986; SRDB Ref ID: 29727, pdf pp. 4-5

NIOSH, 2004, *Estimation of Ingestion Intakes*, Rev. 0, Office of Compensation Analysis and Support (OCAS); OCAS-TIB-009, National Institute for Occupational Safety and Health (NIOSH); April 13, 2004.

NIOSH, 2006, *Report on Residual Radioactive and Beryllium Contamination at Atomic Weapons Employer Facilities and Beryllium Vendor Facilities*, National Institute for Occupational Safety and Health, December 2006; http://www.cdc.gov/niosh/ocas/ocasawe.html#residcont

NIOSH, 2007, *SEC Petition Evaluation Report Petition SEC-00079*, National Institute for Occupational Safety and Health, November 28, 2006; SRDB Ref ID: 39873.

NRC, 1986, Memo from George McCann to William Mura (Dow), Nuclear Regulatory Commission, October 3, 1986; SRDB Ref ID: 29727, pdf pp. 2-3

NUREG 1400, *Air Sampling in the Workplace*, U.S. Nuclear Regulatory Commission; September 1993; http://www.hss.doe.gov/HealthSafety/WSHP/radiation/NUREG-1400.pdf

Nussbaumer, 1962, Memo from Donald Nussbaumer, Dow Chemical Company, January 15, 1962; SRDB Ref ID: 40439.

ORNL, 1990, *Preliminary Results of the Radiological Survey at the Former Dow Chemical Company Site, Madison, Illinois*; ORNL/TM-11552, W. D. Cottrell and J. K. Williams; December, 1990; SRDB Ref ID: 3947

Pangea, 2005, *Final Radiological Characterization Report on the Spectrulite Consortium Madison, IL Facility*, Pangea Group, March, 2005; SRDB Ref ID: 42408.

Shrader, 1959, *Air Sample Data and Calculations*, S. A. Shrader; Dow Chemical Corporation; December 16, 1959; SRDB Ref ID 39914

Silverstein, 1957, *Industrial Hygiene Experience with Magnesium-Thorium Alloys*, Lawrence G. Silverstein, Dow Chemical Corporation, June 19, 1957; SRDB Ref ID: 29269.

Stein, 1982, *Radiological Survey Conducted During the 8/10/81 HM21A Casting Campaign*, T. S. Johnson; Consolidated Aluminum Corporation - Madison Plant; September 10, 1981; SRDB Ref ID: 40440

USACE, 1999, *Formerly Utilized Sites Remedial Action Program St. Louis Sites, Community Relations Plan*, Revision 1, U.S. Army Corps of Engineers, January 1999; SRDB Ref ID: 43878

USACE, 2000, *Post-Remedial Action Report for the Madison FUSRAP Site*, USACE Review Draft, U.S. Army Corps of Engineers, September 2000; SRDB Ref ID: 42409.

USACE, 2001, *Formerly Utilized Sites Remedial Action Program St. Louis Sites, Community Relations Plan*, Revision 3, U.S. Army Corps of Engineers, January 2001; SRDB 40457

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Attachment 1: Data Capture Matrices for Dow Chemical, Madison, Illinois

Table A1-1: SUMMARY OF SRDB HOLDINGS RELATED TO DOW MADISON

(This table spans two pages)

Data Capture Information	General Description of Documents Captured	Date Completed	Uploaded
Primary Site/Company Name: Dow Chemical, Madison, IL 1947-1969 Other Site Names: Spectrulite Consortium 1986-Present CONALCO 1973-1986 CONALCO-Phelps Dodge Aluminum Corp. 1969-1973	See DOW HQ, OCAS, NRC HQ, Stan A. Huber Consultants, Pangea Group, Illinois Emergency Management Agency below.	N/A	N/A
State Contacted: Illinois Emergency Management Agency	Licensing documents, decommissioning plans and surveys.	05/13/2008	9
DOE LM Considered Sites	FUSRAP survey.	08/28/2003	1
NRC Agencywide Document Access and Management (ADAMS)	FOIA requests and responses, licensing, and correspondence.	01/12/2008	2
Battelle Website	No relevant data identified.	02/07/2008	0
Comprehensive Epidemiologic Data Resource (CEDR)	No relevant data identified.	04/08/2008	0
DOE Hanford Declassified Document Retrieval System (DDRS)	No relevant data identified.	04/08/2008	0
DOE OpenNet	Metabolism & biological effects of Pu, Po, Ra, Th, U, and Pb-212.	01/09/2008	1
DOE Office of Scientific& Technical Information (OSTI) Energy Citations	No relevant data identified.	04/10/2008	0
DOE Office of Scientific& Technical Information (OSTI) Information Bridge	Rad safety considerations for thorium handling.	01/09/2008	3
Google	Thorium information, FUSRAP documents, general information.	02/13/2008	35
National Academies Press (NAP)	No relevant data identified.	04/08/2008	0
National Nuclear Security Administration (NNSA) - Nevada Site Office	No relevant data identified.	04/08/2008	0
Washington State University (United States Transuranium and Uranium Registries)	No relevant data identified.	04/08/2008	0
Claimant	Information regarding former Dow president.	03/09/2007	1

Table A1-1: SUMMARY OF SRDB HOLDINGS RELATED TO DOW MADISON

(This table spans two pages)

Data Capture Information	General Description of Documents Captured	Date Completed	Uploaded
Dow HQ	Rad safety assessments and bulletins, radiological survey results, Mg-Th alloy product specifications, annual IH summaries, licenses and licensing correspondence, affidavits, and purchase orders.	01/09/2008	62
DOE Germantown	General facility information.	06/01/2003	2
Kansas City NARA	DOE site remediation authority determination.	06/22/2005	1
NRC Public Reading Room	Licensing correspondence and inspection reports including survey and air monitoring results. Review of CONALCO decommissioning plans, IH experience with Mg-Th alloys including welding, and license exemption request.	01/29/2007	104
Oak Ridge	Site description and FOIA responses.	08/07/2007	7
Savannah River Site	Trip report, FOIA requests and responses.	08/07/2007	8
OCAS	Litigation summary, research paper on LEU fuel, SEC petition with affidavits, and request for certain records.	01/08/2008	4
OCAS Worker Outreach	General information from the 08/2006 Worker Outreach Meeting.	09/25/2006	1
Kirkland & Ellis, LLP	Letter describing Dow Chemical's records retention policies and search.	02/16/2007	1
Pangea Group	Spectrulite air sample results summary from 2006 rafter decontamination.	03/17/2008	1
SAIC	Radiation exposure summaries, 1960 and 1961.	09/02/2004	2
Stan A. Huber Consultants	Low level rad waste manifest and sample analysis.	03/14/2008	1
First Gov Website	Site activity summary.	10/26/2007	1
Wikipedia	Thorium information.	01/14/2008	1
Unknown	Site description and preliminary results of the 1990 radiological survey.	N/A	8
TOTAL			256

Table A1-2: INTERNET DATABASE SEARCHES RELATED TO DOW MADISON

(This table spans four pages)

DATABASE/SOURCE	KEYWORDS / PHRASES	HITS	UPLOADED
DOE OSTI Information Bridge http://www.osti.gov/bridge/advancedsearch.jsp COMPLETED 01/09/2008	dow madison CONALCO	431	3
DOE OpenNet http://www.osti.gov/opennet/advancedsearch.jsp COMPLETED 01/09/2008	CONALCO madison site Uranium Extrusion DOW Chemical	136	1
NRC ADAMS Reading Room http://www.nrc.gov/reading-rm/adams/web-based.html COMPLETED 01/12/2008	dow madison DOW Madison IL DOW Madison Site, Madison IL DOW Madison dow madison uranium extrusion madison IL	3,464	2
Wikipedia http://www.wikipedia.com COMPLETED 01/14/2008	Hazards and Properties of Thorium	1	1
Battelle Website http://www.battelle.org COMPLETED 02/07/2008	Michigan Michigan Metallurgical Lab Metallurgical Lab	43	0
Google http://www.google.com COMPLETED 02/13/2008	madison uranium rod straightening Mallinckrodt Madison Mallinckrodt uranium straightening Mallinckrodt Dow Uranium Contract "dow chemical" "madison site" "uranium" spectrulite "madison site" extrusion	686,992	35

Table A1-2: INTERNET DATABASE SEARCHES RELATED TO DOW MADISON

(This table spans four pages)

DATABASE/SOURCE	KEYWORDS / PHRASES	HITS	UPLOADED
	spectrulite uranium		
	Uranium Extrusion madison site madison IL		
	Mallinckrodt Madison		
	Mallinckrodt uranium straightening		
	Mallinckrodt DOW contract uranium		
	Dow Madison Americium		
	Dow Madison Thoron		
	CONALCO Thoron		
	Spectrulite Thoron		
	Consolidated Aluminum Thoron		
	Dow Madison Thorium		
	Dow Madison Chemical 10-66		
	Dow Madison Chemical 10-12		
	Dow Madison Ionium		
	Dow Madison myrnalloy		
	Dow Madison UX1		
	Dow Madison UX2		
	Battelle Michigan Metallurgical Laboratory		
	Battelle Metallurgical		
	Battelle Metallurgical Michigan		
	Battelle Michigan		
	Dow Madison Th230		
	Dow Madison Th 230		
	Dow Madison Th 230 or Th-230 or Th230		
	Dow Madison Th-230		
	Spectrulite th 230		

Table A1-2: INTERNET DATABASE SEARCHES RELATED TO DOW MADISON

(This table spans four pages)

DATABASE/SOURCE	KEYWORDS / PHRASES	HITS	UPLOADED
	Spectrulite th-230		
	Th-232 Magnesium Casting Dross		
	Spectrulite Th230		
	Spectrulite th-230		
	US Federal Court Michigan Eastern District		
	"dow chemical" "madison site"		
	dow uranium rod straightening		
	CONALCO		
	"Consolidated Aluminum"		
	madison site uranium extrusion process		
	DOW Chemical Madison Site		
	Thorium Magnesium Dosimetry		
	"Thorium Magnesium" and Dosimetry		
	"Thorium Magnesium" and Properties		
	Thorium alloys		
	"Magnesium Thorium" and hazards		
	"Thorium Production Technology"		
	"Health and Safety Aspects of Thorium Production"		
	"Health Hazards Associated with Rolling Normal and Enriched Uranium"		
	Industrial Hygiene and Medical Survey of a Thorium Refinery		
	"Thorium Hazards" in Title		
	"Thorium Dosimetry" in Title		
	Thorium Handling in Title		
	Thorium Magnesium in Title		
	"Thorium Hazards" in Title		

Table A1-2: INTERNET DATABASE SEARCHES RELATED TO DOW MADISON

(This table spans four pages)

DATABASE/SOURCE	KEYWORDS / PHRASES	HITS	UPLOADED
	"Thorium Dosimetry" in Title Thorium Handling in Title Thorium Magnesium in Title Thorium Metabolism "Thorium Hazards" in Title "Thorium Dosimetry" in Title Thorium Handling in Title Thorium Magnesium in Title		
Hanford DDRS http://www2.hanford.gov/declass/ COMPLETED 04/08/2008	DOW Madison Madison	2	0
National Academies Press http://www.nap.edu/ COMPLETED 04/08/2008	DOW Madison Madison	481	0
NNSA - Nevada Site Office www.nv.doe.gov/main/search.htm COMPLETED 04/08/2008	DOW Madison Madison	4	0
DOE CEDR http://cedr.lbl.gov/ COMPLETED 04/08/2008	CEDR http://cedr.lbl.gov	0	0
U.S. Transuranium & Uranium Registries http://www.ustur.wsu.edu/ COMPLETED 04/08/2008	DOW Madison Madison	5	0
Energy Citations Database http://www.osti.gov/energycitations/ COMPLETED 04/10/2008	"Dow Madison" Dow Madison	571	0

Table A1-3: OSTI DOCUMENTS REQUESTED FOR DOW MADISON

DOCUMENT NUMBER	DOCUMENT TITLE	REQUESTED	RECEIVED
None Requested			

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Attachment 2: Reconstruction of Dose Resulting from Intake of Residual Thorium at Dow Chemical from 1961 through 2006

1.0 Introduction

Dow Madison supplied the Atomic Energy Commission (AEC) with both materials and services from January 1, 1957 through December 31, 1960. Among these materials and services, Dow Madison provided magnesium-thorium (Mg-Th) sheets and plates to Mallinckrodt and other AEC facilities. The DOE has stated that in 1957 and 1958 Dow Madison supplied the AEC (via the Mallinckrodt site) with Mg-Th plates and sheets, and that during the 1957 and 1958 time period, these types of plates and sheets were used in atomic weapons (DOE, 2008). The DOE concluded that, for the years 1957-58: (1) Dow Madison probably produced material for use by the AEC; (2) the material emitted radiation; (3) the material could have been used in the production of an atomic weapon; and (4) Dow Madison's work with Mg-Th plates and sheets is, therefore, a covered AWE operation (DOE, 2008). The Dow Madison AWE operations period (1957 through 1960) has already been designated part of the Special Exposure Cohort. The SEC evaluation determined that doses received from potential exposure to uranium contamination during the residual period (1961 through 2006) can be bounded; this bounding methodology is presented in the Dow Madison SEC Evaluation Report (NIOSH, 2007). This analysis only considers the bounding of doses received from potential exposure to thorium during the residual period. Thorium operations are discussed in Section 4.1 of Addendum 2. An understanding of thorium operations and the pertinent data during the AWE operations period (discussed below) is required in order to establish the foundation and assumptions for bounding thorium doses during the residual period.

2.0 Data Considered

Empirical data and process descriptions of arc-melting of thorium metals are provided in a formal study (Lowery, 1962). Arc-melting was used at Dow Madison. While the Lowery data are not used directly in determining intake in the bounding analysis, the study is important to demonstrate expected air concentrations of thorium and thorium progeny. The study also measured airborne activity (breathing zone and general area) in the major task areas involved with arc-melting thorium. Air sampling data obtained at Dow Chemical, Midland for Mg-Th operations are provided in a Health Physics Society presentation document (Silverstein, 1957).

NIOSH analyzed the available data and bounded the airborne activity during the residual period using the highest general area air sample collected from 1957 through 1959 (Hoyle, 1957; Dow, 1959; Shrader, 1959). Process and breathing zone samples were excluded, the rationale being that general area air samples collected during operations would adequately represent contributions from both re-suspension of surface contamination and dispersion of process releases and, as such, would bound the contribution from re-suspension of surface activity alone during the residual contamination period. In all, NIOSH has thirteen general area results for the years 1957 through 1960.

These air monitoring data are presented in Table 2-1. Only two of the thirteen results were positive. All results were converted to pCi/m^3 by using the specific activity of thorium-232. For values reported as < n (e.g., < 0.001), the numeric value was used as the absolute value (e.g., < 0.001 = 0.001) and converted to pCi/m^3.

Table 2-1: Thorium Air Monitoring Data

Task, Area or Process	Time Frame	SRDB Ref ID	Sample ID	Reported Thorium (mg/m3)	Calculated Conc. (pCi/m3)
R. M. Salvage (range of results)	Dec-57	39912, pdf pg 7		0.018	2.00
R. M. Salvage (range of results)	Dec-57	39912, pdf pg 7		0.036	4.00
Rolling steam annealed HK31 in #2 Mill (range of results)	Mar-59	39912, pdf pg 7		<0.009	1.00
Rolling steam annealed HK31 in #2 Mill (range of results)	Mar-59	39912, pdf pg 7		<0.015	1.70
Centrifuge - HK31 sludge	Dec-59	39914, pdf pg 7	10	<0.010	1.11
Centrifuge - HK31 sludge	Dec-59	39914, pdf pg 7	12	<0.011	1.22
Near instrument panel	Dec-59	39914, pdf pg 7	9	<0.011	1.22
Next to drums in sludge recovery	Dec-59	39914, pdf pg 7	14	<0.011	1.22
Sludge recovery	Dec-59	39914, pdf pg 7	6	<0.011	1.22
Sludge recovery	Dec-59	39914, pdf pg 7	8	<0.011	1.22
Control panel	Dec-59	39914, pdf pg 7	11	<0.013	1.44
Near control panel	Dec-59	39914, pdf pg 7	2	<0.023	2.56
Near control panel	Dec-59	39914, pdf pg 7	4	<0.076	8.44

Oak Ridge National Laboratory (ORNL) performed a radiological survey at the Dow Madison site in March 1989 and published a survey report in December 1990 (ORNL, 1990). Among the data published in the report are results from surface smears and dust samples taken in Building 6 where uranium extrusion and thorium processing were performed. ERG collected soil samples and air monitoring data prior to, and after, the 1992 waste yard remediation (Huber, 1998; Baker, 1992).

Pangea performed worker and area air monitoring during thorium clean-up operations conducted in 2006. Pangea Group monitored workers for a four-month period (June through October) for exposure to airborne thorium. Air monitoring results were provided for workers wearing respiratory protection, for workers working using no respiratory protection, and for the perimeter stations. Workers involved in vacuuming and direct removal of dust wore respirators. A Pangea memo states that after Pangea collected information on the workers involved in clean-up activities for one month, it was decided that because airborne activity levels were below 10% of the Derived Air Concentration (DAC) values, workers would no longer be required to use respiratory protection for vacuuming activities (Cushman, 2008). The highest air concentrations measured for workers wearing no respiratory protection, and at the perimeter stations, would have represented airborne conditions that would have been present in the latter year of the residual period during operations that resulted in re-suspension of thorium dust. The maximum air concentrations observed were 9.94% of DAC based on Class Y thorium-232 at the perimeter, and 9.67% of DAC for workers not wearing respiratory protection. The corresponding DAC for Class Y thorium-232 is 1.0 pCi/m^3.

3.0 Exposures to Residual Thorium

Internal exposures to thorium during the residual period potentially resulted from corrosion of stored material, re-suspension of dust, scrap handling, scrap cutting, and loss of containment of disposed materials. Internal exposures to thorium can be bounded based on the available information on the Dow Madison alloy process, the ventilation, the protections employed, and the decay/equilibrium assumptions provided in the Silverstein presentation (Silverstein, 1957).

A statistical analysis of the thirteen data points presented in Table 2-1 would provide uncertain results since only two of the results were reported as positive. The greatest positive result was 4 pCi/m^3. However, the greatest result when all data are considered is 8.44 pCi/m^3. This value was used to maximize the concentration in air of Th-232 during AWE operations with Mg-Th alloy.

Given the available process knowledge reported by Dow Chemical and available air monitoring results, NIOSH considers the maximum air concentration (8.44 pCi/m^3 of Th-232) derived from the data in Table 2-1 to adequately bound the air concentration for potential internal exposures to residual AWE thorium at the start of the residual radiation period (beginning on January 1, 1961).

Contemporary estimates of airborne radioactivity can be derived by using the 1961 air concentration and the air monitoring data obtained in 2006 (Cushman, 2008). Based on removal mechanisms described in ORAUT-OTIB-0070, an exponential model was used to fit the 1961 air concentration and the 2006 data:

A(residual period) = A(operations) * $e^{-\lambda t}$ with t being the length of time between the two air concentration measurements (2006 and 1961, respectfully). This equation was then solved for the factor λ.

The maximum derived air concentration for non-protected operations measured at Dow Madison in 2006 was 0.0994 pCi/m^3 (9.94% DAC). Using the equation above yields

$\lambda = 0.0987 \text{ year}^{-1}$

Using the factor λ, calculated above, air concentrations may be calculated for each year (the air concentration is assumed to be steady for the entire year) and annual inhalation intakes may be calculated by multiplying the concentration value times 1.2 m^3/hr and 2000 hours/yr. For 2006, the annual intake was calculated to be 239 pCi. Annual inhalation intakes of Th-232 for all years are shown in Table 3-2.

Table 3-2: Annual inhalation intakes

Year	Thorium-232 (pCi/yr)	Year	Thorium-232 (pCi/yr)
1/1/1961	20256	1/1/1984	2092
1/1/1962	18352	1/1/1985	1896
1/1/1963	16627	1/1/1986	1718
1/1/1964	15065	1/1/1987	1556
1/1/1965	13649	1/1/1988	1410
1/1/1966	12366	1/1/1989	1277
1/1/1967	11204	1/1/1990	1157
1/1/1968	10151	1/1/1991	1049
1/1/1969	9197	1/1/1992	950
1/1/1970	8332	1/1/1993	861
1/1/1971	7549	1/1/1994	780
1/1/1972	6840	1/1/1995	707
1/1/1973	6197	1/1/1996	640
1/1/1974	5614	1/1/1997	580
1/1/1975	5087	1/1/1998	525
1/1/1976	4609	1/1/1999	476
1/1/1977	4176	1/1/2000	431
1/1/1978	3783	1/1/2001	391
1/1/1979	3428	1/1/2002	354
1/1/1980	3105	1/1/2003	321
1/1/1981	2814	1/1/2004	291
1/1/1982	2549	1/1/2005	263
1/1/1983	2310	1/1/2006	239

Internal doses from ingestion can then be bounded using the annual inhalation intake rates. Per OCAS-TIB-009, the intake can be clamant-favorably reconstructed by assuming the total daily ingestion intake equals 0.2 times the air concentration (NIOSH, 2004). The annual ingestion intake is then calculated based on 250 workdays per year. The same clearance factor that is used with inhalation dose determinations should be used with accompanying ingestion dose determinations. Annual ingestion intakes of Th-232 are shown in Table 3-3.

Table 3-3: Annual ingestion intakes

Year	Thorium-232 (pCi/yr)	Year	Thorium-232 (pCi/yr)
1/1/1961	422.0	1/1/1984	44.1
1/1/1962	382.3	1/1/1985	40.0
1/1/1963	346.4	1/1/1986	36.3
1/1/1964	313.9	1/1/1987	32.9
1/1/1965	284.4	1/1/1988	29.9
1/1/1966	257.7	1/1/1989	27.2
1/1/1967	233.5	1/1/1990	24.7
1/1/1968	211.6	1/1/1991	22.4
1/1/1969	191.7	1/1/1992	20.4
1/1/1970	173.8	1/1/1993	18.6
1/1/1971	157.5	1/1/1994	16.9
1/1/1972	142.7	1/1/1995	15.4
1/1/1973	129.3	1/1/1996	14.0
1/1/1974	117.2	1/1/1997	12.8
1/1/1975	106.2	1/1/1998	11.7
1/1/1976	96.3	1/1/1999	9.9
1/1/1977	87.3	1/1/2000	9.0
1/1/1978	79.1	1/1/2001	8.1
1/1/1979	71.8	1/1/2002	7.4
1/1/1980	65.1	1/1/2003	6.7
1/1/1981	59.0	1/1/2004	6.1
1/1/1982	53.5	1/1/2005	5.5
1/1/1983	48.6	1/1/2006	5.0

3.1 Exposures to Thorium Slag

Intakes must also be considered from potential exposures arising from the waste yard through the end of 1992 when remediation was completed (Baker, 1992). Workers involved in waste yard activities would have been potentially exposed to these intakes, but not to both the building and waste yard intakes at the same time.

There were 130,000 pounds (59,000 kg) of thorium in the yard, as reported in 1986 (Mura, 1986). It is assumed that Dow Chemical put solid slag waste in this yard from 1957 through 1969. While waste was absorbed in soil, it is possible that some soil and waste material was blown airborne or spread via equipment and workers after dumping/bulldozing operations. Although materials in the waste yard were covered, some breach of covering is assumed to be plausible. As a bounding estimate, it is assumed that the entire AWE waste inventory was available for release to the environment, and that it was released in equal annual quantities (1844 kg) from 1961 through 1992 using a release fraction of 0.001. Using the specific activity of Th-232, there are 0.208 curies of radioactivity in 1844 kg.

The annual inhalation intake (I) can be calculated using:

1. $I = 10^{-6} * Q * R * C * D$ (NUREG-1400),
   where:

   Q = annual activity of radionuclide = 0.208 Ci

   R = estimated release fraction = 0.001
   (NUREG-1400 recommends R = 0.001 for solids)

   C = confinement factor = 1
   (NUREG-1400 recommends C = 1 for open areas)

   D = dispersibility factor = 1
   (No dispersion energy is assumed to be added to the waste after disposal in the yard)

2. From this equation, I is determined to be:

   $I = 10^{-6} * 0.208 * 0.001 * 1 * 1$
   I = 2.08E-10 Ci per year
   I = 208 pCi per year (inhalation)

Since the intake calculated for yard workers (208 pCi/yr) is bounded by that calculated in Section 3.0, above, the higher intake rates provided in Table 3-2 (for inhalation) and Table 3-3 (for ingestion) should be assumed for all workers.

3.2 Exposure to Thoron

Thoron (Rn-220) and its progeny are part of the thorium decay series and thoron air contamination would have been present during the operations period. Dow Madison monitored for thoron contamination in 1959 during operations that used HK-31 (the alloy containing the highest percentage of thorium). These monitoring data (Shrader, 1959) are shown in Table 3-4.

Table 3-4: Thoron Air Monitoring Data

Task, Area or Process	Sample Date	SRDB Ref ID	Sample ID	Thoron and Progeny (Ci/l)
In Pot Room	Dec-59	39914, pdf p. 7	3	2.0E-12
Near control panel	Dec-59	39914, pdf p. 7	4	1.0E-13
Sludge recovery	Dec-59	39914, pdf p. 7	6	3.7E-14
Near instrument panel	Dec-59	39914, pdf p. 7	9	3.4E-14
Centrifuge - HK31 sludge	Dec-59	39914, pdf p. 7	10	3.2E-14
Near control panel	Dec-59	39914, pdf p. 7	2	3.1E-14
Next to drums in sludge recovery	Dec-59	39914, pdf p. 7	14	2.3E-14
Centrifuge - HK31 sludge	Dec-59	39914, pdf p. 7	12	2.0E-14
In Pot Room	Dec-59	39914, pdf p. 7	7	2.0E-14
Control panel	Dec-59	39914, pdf p. 7	11	1.6E-14
In Pot Room	Dec-59	39914, pdf p. 7	1	1.3E-14
In Pot Room	Dec-59	39914, pdf p. 7	5	1.2E-14
Sludge recovery	Dec-59	39914, pdf p. 7	8	5.0E-15

A z-score analysis was applied to these data, as shown in Table 3-5. The z-score for an item indicates how far, and in what direction, that item deviates from the mean of its distribution, expressed in units of that distribution's standard deviation. The resulting Rn-220 concentration at the 95th percentile was 1.82E-13 Ci/l (0.182 pCi/l).

Table 3-5: Z-Score Analysis of Thoron Air Monitoring Data

Rank	Thoron (Ci/l)	Ln (Data)	Percentile	Z-Score
1	5.00E-15	-32.93	0.04	-1.77
2	1.20E-14	-32.05	0.12	-1.20
3	1.30E-14	-31.97	0.19	-0.87
4	1.60E-14	-31.77	0.27	-0.62
5	2.00E-14	-31.54	0.35	-0.40
6	2.00E-14	-31.54	0.42	-0.19
7	2.30E-14	-31.40	0.50	0.00
8	3.10E-14	-31.10	0.58	0.19
9	3.20E-14	-31.07	0.65	0.40
10	3.40E-14	-31.01	0.73	0.62
11	3.70E-14	-30.93	0.81	0.87
12	1.00E-13	-29.93	0.88	1.20
13	2.00E-12	-26.94	0.96	1.77

RESULTS:		
GM (50th):	3.14E-14	Ci/l
GM*GSD (84th):	1.10E-13	Ci/l
GSD:	3.505	
95th Percentile:	1.82E-13	Ci/l
r squared:	0.719	

3.3 Summary of Internal Intakes

Intake values for inhalation and ingestion should be assigned for each year of employment. Equal intake amounts should be attributed to Th-232, Th-228, and Ra-228. An intake of Th-230 should be added based on a 2:1 activity ratio of Th-230 to Th-232 (Baker, 1992). Thoron intake should also be assigned for each year of employment. These intakes must be added to intakes arising from potential exposures to residual uranium, as discussed in the Evaluation Report for Dow Madison Petition SEC-00079 (NIOSH, 2007).

3.4 External Exposures

External electron and photon exposures resulting from exposure to thorium feed can be reconstructed using dose rate data presented by Silverstein and by Levy (Silverstein, 1957; Levy, 1957). Exposure rate data obtained in 1982 are useful in reconstructing potential external doses. External radiation measurements were obtained for CONALCO during commercial thorium processing and during non-processing periods and represent exposure rates generated from materials of varying in-growth. CONALCO concluded in the document that all external radiation levels were maintained within allowable limits. Exposure rates measured in all areas, except near the thorium scrap bins and storage annex, ranged from 0.01 to 0.05 mR/hr at distances varying between one and ten feet. The highest recorded exposure rate (0.7 mr/hr at one foot) was obtained near the thorium storage area and scrap bins, where AWE era materials were stored. The exposure rate recorded at ten feet ranged from 0.1 to 0.2 mr/hr.

While thorium scrap and wastes generated during the AWE operations period would have only partially contributed to the measured photon exposure rates, the measured exposure data are assumed to represent the doses from those AWE materials with no scaling factor applied. These data can be used to bound the external photon dose by assuming that all workers were continuously exposed to the maximum recorded exposure rate (0.7 mr/hour) during a 40-hour week. In this scenario, a worker would have received 28 mrem/week whole-body photon exposure per week or 1.400 rem/year. In considering the electron exposure rate, Heatherton reported that beta dose rates due to thorium metal with in-growth of daughters were approximately in a 1:1 ratio with the photon dose rate (Heatherton, 1955). Therefore, an annual beta dose of 1.400 rem/year will be used for the electron dose for all workers. The photon and electron doses are additive to the photon and skin dose assigned from potential exposures from residual uranium (ORAUT- OTIB-0004; Eckerman, 1993).

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