White Paper

Review of the NIOSH "White Paper on Fernald Th-230 and Other Associated Radionuclides – Rev. 7"

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May 2010

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1.0 INTRODUCTION

During the Fernald Work Group meeting held on January 29, 2010, the Work Group discussed six issues identified by SC&A. Issue 4 is concerned with NIOSH's approach for reconstructing the doses to workers exposed to Ra-226 and Th-230. One aspect of this issue deals with Fernald operations where workers could have been exposed to material that contained relatively high levels of Th-230, especially under conditions where there were relatively low levels of Ra-226 and uranium. NIOSH addresses this issue in "White Paper on Fernald Th-230 and Other Associated Radionuclides – Rev. 7," by Bryce L. Rich and Paul Ruhter (January 6, 2010). During the Work Group meeting, SC&A was tasked with reviewing that white paper. This report is provided in response to that request.

1.1 Purpose of NIOSH's White Paper

The stated purpose of NIOSH's white paper is to "provide information necessary to perform dose reconstruction for those workers at the Feed Materials Production Center (FMPC) who may have been exposed to, but not monitored for, specific uranium decay contaminants that were present in plant processes." This paper specifically addresses the expressed concern for elevated Th-230 concentrations, which is most evident in the isotopic characterization of raffinates stored in Silos 1, 2, and 3. Other uranium decay product isotopes are also addressed, including radium and its decay products. Doses from the intake of radium resulting from a short-term operation of dumping barrels of hot raffinates from the processing of pitchblende ores at other plants (primarily Mallinckrodt) into Silos 1 and 2 were discussed briefly in previous meetings of the Procedures Subcommittee and in another SC&A white paper (previously distributed to the Work Group). Those discussions centered around ORAUT-OTIB-0025, which describes NIOSH's generic approach to reconstructing Ra-226 body burdens and intakes based on radon breath analysis.

As stated in the NIOSH white paper, the primary concern of the white paper is:

> *Th-230, which is a long-lived decay product of U-234, which in turn is a decay product of U-238 – all of which would be present in the primary feed materials (pitchblende ores and uranium mill yellowcake) during the early years from startup to 1971.*

1.2 Basic Method for Calculating Th-230 Doses as Described in the NIOSH White Paper

NIOSH proposes to calculate bounding intakes of Th-230, based on intakes from uranium, as described in the following excerpt from the NIOSH white paper:

> *Since uranium was the primary material in the process and was low in specific activity, heavy metal toxicity from the uranium was considered the initial and limiting health concern. An extensive urine sampling program was administered in concert with an equally comprehensive air sampling program to guide personnel protection programs, i.e., respiratory protection, improvements in*

process containment, etc. For this reason, the approach developed in this paper has determined claimant favorable values for the historical levels of the trace quantities of contaminant isotopes relative to the levels of uranium intake, which was determined by a routine urine bioassay program. A dose reconstruction approach is proposed that once a determination of the intake of uranium has been made from bioassay data, unmonitored intakes of the other isotopes can be added based upon a bounding analysis of the levels that could have been encountered relative to the levels of uranium present in the given work areas.

With respect to reconstructing doses from Th-230, the NIOSH white paper presents a dose reconstruction strategy that takes advantage of the proportion of Th-230 relative to U-238 and changes in operations as a function of time, as described in the following excerpt from the NIOSH white paper:

The exposure of workers to Th-230 plus other daughter products in Plants 2/3 and 1 can be appropriately bounded by adding an intake of Th-230 that is equal to the intake of U-234 or U-238 in natural uranium determined in mass units. The isotopic ratios in Silo 3 or Silos 1 and 2 to uranium are not used as defaults, since the recorded air activity levels with the associated exposure potential within the raffinate areas (represented by Silo 3 analyses) were so demonstrably low. The primary elevated Th-230 plus daughters exposure potential existed primarily in the high air activity areas in Plant 2/3 and Plant 1, which sampled, mixed, etc., ores and concentrates also.

Following the major process of concentrate feeds in the early to mid 1970s, process of uranium feeds shifted to other materials without elevated Th-230 contaminants. All concentrates (AEC stockpile) were consumed in 1977 and other materials, including enriched uranium, became the primary feeds. Hence not only the total production but specifically the use of concentrate feeds (with elevated Th-230 and daughters) were reduced to less than 10% of previous highs. Thus the values in Table 3 should be reduced to 10% as a claimant favorable default to account for possible continuing Th-230 exposures. Also, in order to account for the fact that internal process equipment and some residual process materials that could have Th-230 contaminants existed in the plant the assumptions outlined in OTIB-70 were used to demonstrate that aging of contaminants reduce the resuspension of those contaminants into exposure areas to less than 1%, which further validates the reduction of default values to 10% as a conservative assumption.

2.0 FINDINGS ASSOCIATED WITH NIOSH'S PROPOSED METHOD OF CALCULATING TH-230 DOSES

The NIOSH white paper describes four different categories of areas where workers could have been exposed to Th-230, as follows:

(1) Areas where uranium and U-238 chain daughters, including Th-230 and Ra-226, are present, as for example, the pilot plant (during the initial operation of FEMP); Plant 1 (sampling, homogenization and milling operations); Plants 2 and 3 (areas where chemical processing of uranium ores took place, through the three-step process; digestion, extraction, and denitration); Plant 8 (Recovery Plant). Facilities and operations that fall within this category are distinguished by the fact that U-238 and its progeny are all present. For these areas, NIOSH proposes to calculate U-238 intakes from bioassay results and to add an intake of Th-230 that is equal to the intake of U-238. The activity ratio of Th-230/U238 intakes may be discussed but, in theory, bioassay data that provide information on the concentration of uranium in urine can be used directly to estimate the intake rate of not only uranium, but also its progeny, including Th-230 and Ra-226, if workers in these areas did not perform additional jobs where U-238 is not present..

(2) The raffinate areas located in Plant 3: In these areas, Th-230 is present after separation from uranium. Ra-226 is present in some of the operations, but not in all of the processes conducted in the raffinate areas of Plant 3. As explained in NIOSH's white paper:

> *…the objective of the extraction processes was to separate uranium from the feed stream; the impurities, i.e., anything other than uranium, were extracted into waste streams called raffinates. …*
>
> *The Hot Raffinate Building (3E) was utilized to filter insolubles from UNH and to process the raffinates. The Purex process resulted in raffinate waste streams into which those isotopes and material contaminants were extracted. This is the primary source of contaminants in the Silos, with relatively concentrated Th-230.*

The raffinate areas included hot and cold sides. The liquid raffinate from the extraction process contained valuable metal oxides. These oxides were recovered from the liquid raffinate and placed in the Metal Oxide Storage Tank. There were two streams, depending on where the raffinate originated. Hot raffinates were those resulting from Ra-containing ores, while cold raffinates were Ra-free. Hot raffinates were first processed to remove the Ra. The filter cake was mixed with water and calcium oxide, and the resulting slurry was pumped to the K-65 silos for storage. The purpose of the hot raffinate treatment was to segregate the radium-bearing insolubles from the slurry. The process ended with a precipitate of Ra (Ra cake) and Ra-free filtrate continuously pumped to the combined raffinate area, where it was mixed with a stream of cold raffinate slurry before being evaporated. The Ra cake (K-65) was reslurried with an alkaline solution, and after processing, went to the K-65 storage. (CCC 1951, "Plant 2/3, Institutional History and Exposure Database, produced under the direction of Susan Pinney, 1998")

The filtered hot and cold raffinate streams were received in the combined raffinate area. The combined raffinate stream was evaporated to obtain a concentrated metal nitrate solution [CCC possibly 1956 (date unclear)]. Facilities and operations that fall within this category are distinguished by the fact that Th-230 and/or Ra-226 are present, but workers are exposed to insignificant quantities of uranium. As the exposure to uranium is not significant, uranium bioassay results, if existent, are of no value to calculating Th-230 or Ra-226 exposures. NIOSH's White Paper discards exposures to alpha-emitting nuclides in these areas, by stating that:

> *…the workers in the raffinate areas experienced airborne concentrations that were consistently at the same levels as were assigned to the records clerks and administrative assistants. These levels should be considered ambient levels very near the detection limit of the monitoring equipment. The value of 0.1 MAC (maximum allowable concentration) or NCG (National Lead Concentration Guide) is the same value consistently reported for those areas considered to represent background levels.*

(3) Silo Areas 1 and 2, where Th-230 and Ra-226 are present:

NIOSH White Paper explains that:

> *The raffinate streams from the early Fernald processing (1953 to 1955) of Pitchblende Uranium ores were stored in Silos 1, 2, since they were the property of the Belgian Government Agency. Also in the 1955 to 1958 time period approximately 13,000 barrels of pitchblende ore raffinates were slurried and added to Silos 1 & 2 from another Site.*

Historical core sampling was performed and the mean isotopic values at the upper 95% confidence interval were reported in Table 2 of the White Paper.

During a short period of time (1953–1958) when pitchblende ore raffinates were shipped to Fernald from other AEC sites in approximately 13,000 drums for disposal in Silos 1 & 2, the transfer operations were monitored and radon breath bioassay data were collected. These data are available for use in estimating radium intake, as discussed in ORAUT-OTIB-0025 (2005). NIOSH's white paper does not mention how the radon breath analysis results are going to be used to calculate Th-230 intakes.

NIOSH's White Paper does not make any reference on how to calculate Th-230 or Ra-226 doses to workers involved in other jobs related to Silos 1 & 2 besides the transfer of the 13,000 drums.

(4) The Silo 3 Areas where Th-230 is present in much higher activities than U-238 or Ra-226:

According to the NIOSH white paper:

> *The raffinate streams from the processing of uranium mill concentrate feeds during the 1955 to 1971 time period were stored initially in Silo 3, because they were a dry powder resulting from the acid recovery calcining primarily from domestic and Canadian mines and mills. Later, the extraction process was changed to the use of dilute nitric acid, which allowed the raffinate to be*

neutralized and disposed of directly as a slurry to pit 5, eliminating the need for calcining to recover the nitric acids.

This facility is distinguished by the fact that Th-230 is present in the waste stream at concentrations that are high, relative to the concentrations of uranium and Ra-226. Hence, it might be difficult to estimate Th-230 intake rates for workers that handled this material, because of uncertainties in the proportion of Th-230 to either uranium or Ra-226. NIOSH's White Paper does not make any reference on how to calculate doses to workers involved in jobs related to Silo 3.

Finding 1: The fundamental strategy, as adopted by NIOSH to reconstruct Th-230 intake rates, presents many challenges to the dose reconstructor.

Some of our major concerns are as follows:

(1) For Category 1 areas, the reconstructed Th-230 intakes are only valid for workers that did not perform jobs or spend time in the raffinate areas of Plant 3 or the silo areas, where exposure to uranium was negligible. If the worker is miscategorized with respect to his/her work location, the Th-230 body burden, as estimated for Category Type 1 workers, could be significantly underestimated.

(2) For Category Type 2 exposures, the proposed methodology to estimate Th-230 intakes based on U-238 bioassay is not scientifically valid. It is not possible to estimate U-238 or Th-230 intakes based on bioassay results of U-238 in areas where exposures to uranium were negligible.

(3) For Category Type 3 exposures, the assumption that the intake rate of Th-230 can be reconstructed based on knowledge of the Ra-226 body burden (as derived using radon breath analysis) is valid for the short period of time (1953–1958), when some 13,000 drums of pitchblende ore raffinate were transferred for disposal in Silos 1 and 2. The transfer operations were monitored, and radon breath bioassay data are available upon which to determine radium intake. However, there is some question whether workers that experienced these exposures can be identified, and whether there are sufficient data to construct a coworker model for those workers that might have handled Ra-226 and Th-230, but do not have radon breath analyses.[1]

(4) For Category Type 4 exposures, it is not apparent that the ratio of U-238 to Th-230 in the source material to which a worker might be exposed is known, nor are the jobs performed described in detail. For most jobs involving Silo 3 raffinate stream exposures, U-238

[1] During the review of this draft, questions were also raised regarding a possible limitation of using radon breath analysis to reconstruct Th-230 body burdens, even when the ratio of Ra-226 to Th-230 in the inhaled material is known. The reason for this concern is the possibility that Ra-226 is cleared from the body more rapidly than Th-230. Hence, radon breath analyses might underestimate the Th-230 body burden under some circumstances. NIOSH does not mention how Th-230 intakes should be calculated based on radon in breath analysis.

concentrations are not significant, and uranium bioassay results cannot be used to derive Th-230 intakes.

Many of these fundamental findings are developed in greater detail in the remaining findings. Hence, there is some duplication between these and subsequent findings.

Finding 2. We have concerns regarding the way jobs, and therefore area assignments, are assigned in the white paper.

Specifically, NIOSH does not offer an explanation of how the jobs were divided between Plant 2 and Plant 3, and which jobs were done in areas where the workers might have been exposed to Th-230 in concentrations above equilibrium. This information is important to understanding NIOSH's comparisons of Appendix A tables of daily weighted activity (DWA)[2] for specific jobs in Plant 2/3, Plant 2, and Plant 3. Those comparisons were used by NIOSH to justify an equilibrium isotopic ratio of Th-230 to uranium. The following are examples of disconnects between job assignments, locations, and categorization of workers as belonging to either Category Types 1 or 2 exposures:

(1) The document by Wing and Halcomb (1958) describes the incorporation of the denitration area into Area 3 in 1958.

(2) An Analytical Data Sheet from May 1957 shows that drumming of Australian pitchblendes took place in the Plant 3 Hot Raffinate Area. The general air (GA) and breathing zone (BZ) were much higher than the maximum air concentration (MAC). There is an observation that some operators did not wear respirators. Did drumming of pitchblende occur in Plant 3, as well as in Plant 2? Who were the workers in each area of Plant 2 and Plant 3? Did some workers perform jobs in both plants and in different areas?

NIOSH should present a detailed analysis of the jobs and the areas were workers could have been exposed to Th-230, and of the most probable isotopic concentration in relation to uranium. NIOSH should clarify if workers that performed work in uranium areas might also have worked in areas where exposure to uranium was negligible.

Finding 3. We are concerned with the assumption that there were no exposures in areas where processes were contained in closed piping systems.

For example, pipe leaks were identified in several reports by Wing and Halcomb (1958, 1959), Wing et al. (1962) and Ross et al. (1968) on exposures of personnel in Plants 2 and 3. This contradicts the presumption in the white paper that exposures in the solvent extraction process of Plant 2 were low, because it was a liquid-liquid extraction process essentially contained within a closed piping system. In addition, it contradicts the presumption that the high thorium ratio observed in the Silo 3 materials is associated with the liquid stream contained within an essentially confined system, which presents little if any exposure potential to the workers.

[2] The terms daily weighted activity (DWA) and daily weighted exposure (DWE) are used interchangeably.

Finding 4. We are concerned that the recycling of raffinate materials could contain high concentrations of Th-230 and not the low values assumed in the white paper.

For example, in some operations in areas of Plant 2/3, workers were exposed to Th-230 in concentrations higher than equilibrium in the uranium chain. Due to recycling of raffinate material, intakes that are equal to the intake of U-234 or U-238 in natural uranium determined in mass units do not appear to be claimant favorable; i.e., they are not bounding for the purpose of an SEC evaluation.

Finding 5. Questions regarding the types of exposures experienced by Plant 8 workers.

The White Paper states the following:

> *A few of the uranium concentrate materials from different mills had chemical characteristics which did not allow direct insertion as Plant 2/3 process feed streams, i.e., significant organic contaminants were avoided. Plant 8 furnace facilities were used to "roast" the concentrates that did not meet specifications and drive off volatile chemical contaminants prior to Plant 2/3 processing. In these few cases Plant 8 would have ore concentrates with the elevated Th-230 levels, although these uranium processes would not constitute more than a small fraction of the total exposure potential.*
>
> *The other process streams handled in Plant 8 were scraps and waste products from plants which had processed purified uranium products. Thus, though some additional Th-230 levels would be expected from handling some out-of-specification uranium concentrates, they would not add a significant dose potential.*

For some operations in Plant 8, intakes that are equal to the intake of U-234 or U-238 in natural uranium determined in mass units are not claimant favorable for determining Th-230 intakes.

Finding 6. Questions regarding exposure assumption for the time period from 1970–1989.

For the period after 1970, the white paper states the following:

> *Following the major process of concentrate feeds in the early to mid 1970s, process of uranium feeds shifted to other materials without elevated Th-230 contaminants. All concentrates (AEC stockpile) were consumed in 1977 and other materials, including enriched uranium, became the primary feeds. Hence not only the total production but specifically the use of concentrate feeds (with elevated Th-230 and daughters) were reduced to less than 10% of previous highs. Thus the values in Table 3 should be reduced to 10% as a claimant favorable default to account for possible continuing Th-230 exposures. Also, in order to account for the fact that internal process equipment and some residual process materials that could have Th-230 contaminants existed in the plant the assumptions outlined in OTIB-70 (reference 3) were used to demonstrate that aging of contaminants reduce the resuspension of those contaminants into*

exposure areas to less than 1%, which further validates the reduction of default values to 10% as a conservative assumption.

NIOSH needs to provide the scientific basis to use 10% of the values in Table 3 as a claimant-favorable default. The quantities and type of feed material received by FEMP as a function of time is not shown in detail. NIOSH did not show the time spent by workers when exposed to the different feed materials, nor their correlation with the time uranium bioassay measurements were conducted. NIOSH did not present data on the raffinate treatment for 1970–1989. NIOSH did not discriminate which workers were exposed only to raffinates, and which workers were exposed to both processes. Furthermore, a reduction in the quantity of material processed cannot be assumed to correspond to a reduction in intake by a specific worker, unless the timeframe worked by every worker is proportionately reduced.

Finding 7. Concerns on bounding exposures based on DWAs.

As SC&A has noted in prior reviews, daily weighted activities (DWAs) reflect typical routine exposures (apart from incidents), rather than bounding exposures. In an SEC Petition context, air concentration data needs to be analyzed to yield bounding rather than typical dose. See, for instance, SC&A's white paper on use of DWA data for Th-232 exposure estimation at Fernald prior to 1968 (SC&A 2009).

Finding 8. We are concerned that the airborne dust loading of Th-230 in the raffinate areas was substantially higher than assumed by NIOSH, and thus a method for dose calculations for Th-230 should be available for dose reconstruction in those areas.

NIOSH's white paper states the following:

> *The workers in the raffinate areas experienced airborne concentrations that were consistently at the same levels as were assigned to the records clerks and administrative assistants. These levels should be considered ambient levels very near the detection limit of the monitoring equipment. The value of 0.1 MAC (maximum allowable concentration) or NCG (National Lead Concentration Guide) is the same value consistently reported for those areas considered to represent background levels.*

SC&A has several concerns with this position, as follows:

(1) Concerns relative to the uncertainties related to air sampling.

Air sampling (especially GA samples) can underestimate concentrations in the BZ of a worker, often by an order of magnitude (ICRP Pub. 78, 1997). ICRP SG 3 (2002) further specifies that the use of static samplers does not ensure a representative measurement of exposure of the worker, especially in workplaces where the aerosol release points are discrete and distributed. The DWEs were calculated using GA samples and BZ air samples. The document by Wing and Halcomb (1958) shows that for 1955–1958, the air sampling on the hot raffinate and combined raffinate areas consisted only of GA samples. As discussed before, GA samples can dramatically underestimate exposures.

(2) Concerns regarding the completeness of air sampling data.

The DWA results in Appendix A were not derived using the complete set of results taken during the whole year. The following are some of the reasons for this concern:

- The DWA results in Appendix A were based on sampling during certain months of the year. Area 3 DWAs, in 1958 for example, are the ones registered by Wing and Halcomb (1958) and were based on August to October sampling.

- The document by Halcomb and Huesing (1957), "…reports that numerous leaks had been observed in the calciner and feed hopper area, but that air dust samples were not obtained during the time of these leaks."

- The 1962 DWAs in Appendix A were based on the document Wing et al. 1962, and cover exposures from January to March 1962. This document shows only GA samples taken at the Hot Raffinate Building. On the other hand, the "Analytical Data Sheet Document Plant 3 Hot Raffinate, ^{226}Ra and ^{230}Th, and Combined Raffinate, ^{230}Th Air dust Samples," 1962, shows BZ air sampling results for an operator shoveling solvent cake in Oliver Filter that are higher than the MAC in the Plant 3 Hot Raffinate Building. The DWAs in Appendix A for 1962, Plant 3, do not show these results.

- An Analytical Data Sheet from May 1955 ("1955 Plant 3 Combined Raffinate BZ and GA results Th-230") reports raw data for GA and BZ samples results in the Combined Raffinate area of Plant 3. It shows some results with concentrations above the MAC in the control room and for workers operating the batch conveyor at the calciner. The DWAs in Appendix A for 1955, Plant 3, do not show these results.

- An Analytical Data Sheet from May 1957 ("Plant 3 Hot Raffinate Building Air Dust Samples," 1957) shows several GA results above the MAC in Plant 3 Hot Raffinate area. Breathing zone samples taken in this area were well above the MAC, for example, the result 30,706 dpm/m^3 for an operator using air hoses to unplug the loading chute. Several other operations in the same area (hot raffinate area, filtering pitchblende residues) showed BZ and GA well above the MAC. Breathing zone sample results for Oliver Filter operators were also high. Several GA samples in the Oliver Filter area were much higher than the MAC. These data are not reflected in Appendix A DWAs for Plant 3.

The above 5 items are only examples of data and analytical issues that were not taken into consideration in the development of the DWA tables in Appendix A, which are used in the white paper to demonstrate that exposures experienced by workers in "Plant 3, which housed the raffinate operations, were low, essentially at background levels." The DWA tables should summarize all available data, or a justification for not using all the available data.

Finding 9. Concerns regarding the methods proposed by NIOSH for calculating bounding Th-230 intakes based on uranium bioassay results for Category 2, 3 and 4 areas.

The white paper states that Th-230 intakes should be based upon a bounding analysis of the levels that could have been encountered relative to the levels of uranium present in the given work areas. The white paper states that, in the raffinate processing areas, the levels of uranium were very low, because uranium had been already extracted. The workers in most raffinate operations were essentially not exposed to uranium. Because uranium was not present to any significant extent in these areas, it does not appear to be possible to assign thorium intakes using uranium bioassay results.

Finding 10. Concerns regarding the reconstruction of Th-230 related to Silos 1 and 2 (i.e., the K-65 Silos).

From 1953 until 1958, pitchblende ore containing high concentrations of uranium and uranium daughter products were used as the raw material for the production of uranium products. This ore was obtained from the Shinkolobwe mine in the Belgium Congo. Uranium was separated from the pitchblende ore by the use of the three-phase Purex process—digestion, extraction, and denitration. The aqueous raffinate or waste from this process was pumped into one of two large concrete silos for storage. These residues, which were assigned the code name "K-65," contained small amounts of Th-232 and Th-228, and daughter products of uranium, including Th 230, Ra-226, Rn-222, Pb-210, and Po-210. The raffinate was slurried from the refinery (Plant 2/3) through pipes into Silo 2.

The radium-containing material in K-65 Silo 1 came from another source. Prior to 1952, large amounts of radium-bearing radioactive waste were shipped to the Fernald Site from Mallinckrodt Chemical Works in St. Louis, and eventually stored in the K-65 Silo 1. When the waste material first arrived, however, it was placed in metal drums, which were temporarily stored on a concrete pad near Plant 1. An internal FMPC memorandum indicates that 13,000 55-gallon drums of K-65 material were received at the FMPC during the period September 25, 1951, to July 31, 1952. Other drums of K-65 material were stored in Plant 8 for long periods of time. The drummed material was transferred into Silos 1 and 2 over a 6-year period, between July 1952 and September 1958.

The transfer of K-65 waste material from the 13,000 drums was a manual process that likely exposed workers internally to high airborne levels of contaminants, as well as externally to penetrating radiation (SC&A 2007)

NIOSH's White Paper states that*:*

> *During a short period of time (1953–1958) when pitchblende ore raffinates were shipped to Fernald from other AEC Sites in some 13,000 drums for disposal in Silos 1 & 2, the transfer operations were monitored and radon breath bioassay data are available upon which to determine radium intake. By ratioing to Ra-226 intake it is possible to bound the intakes of the other isotopes that could have been part of an unmonitored intake. See the Draft Radon Breath Analysis white paper*

(previously distributed to the Working Group) and OTIB-25 for a more complete analysis and Dose Reconstruction approach.

ORAUT-OTIB-0025 (2005) was reviewed and its conceptual basis was approved by SC&ANIOSH's white paper does not specify how Th-230 intakes should be calculated from radon breath analysis.

Additional monitoring results are necessary to calculate Th-230 intakes from any other activities related to K-65 silos that are different than the transfer of the 13,000 drums. For any operations in which direct contact with these residues was required, the K-65 silos represented a continuing internal exposure potential from the unusually high concentrations of Ra-226 and its progeny, Pb-210 and Po-210 (these three radionuclides comprise approximately 90% of the total activity in the K-65 materials). The uranium daughter Th-230 was also present in significant quantities (7% to 10%) in this location.

An analytical data sheet from 1955 ("Plant 2, K-65 Metal Oxide Storage of Th-230") describes some operations that took place in March 1955 in the K-65 storage material, where the air concentrations were much higher than the MAC.

Finding 11. Concerns regarding Th-230 exposure to workers involved with Silo 3 material.

Silo 3 was used for the raffinate storage from "cold metal oxide" extraction separations and contained approximately 138,000 cubic feet of raffinate. The feedstock for these processes was uranium concentrates from a variety of uranium mills in the United States and abroad. The material in Silo 3 was calcined prior to storage and was a fully oxidized, fine powder, in contrast to the K-65 material in Silos 1 & 2, which was approximately 30% moisture (ORAUT-TKBS-0017-5, 2004b).

ORAUT-TKBS-0017-2 (2004a) cites the inhalation exposures associated with Th-230 in Silo 3, as follows:

> *The immediate concern involving Silo 3 is the risk of inhalation dose from suspended material following a release. The radionuclide having both the largest specific activity (60 nCi/gm) and the greatest fraction of relative dose (83%) in Silo 3 is Th-230, which is produced from the natural decay of ^{238}U. The primary hazard for workers is the inhalation of the fine powder in the silo. …*

In the SEC Petition Evaluation Report Petition SEC-00046 (2006), it is explained that:

> *…the immediate concern involving Silo 3 was the risk of inhalation dose from suspended material following a release. Thorium-230, which is produced from the natural decay of uranium-238, had the largest specific activity (60 nCi/gm) in Silo 3.*

The NIOSH White Paper would benefit from additional discussion regarding the scenarios that could have resulted in exposures to workers handling or exposed to material in Silo 3. For example, a letter dated March 16, 1956, from [redacted], to Mr. C.L. Karl, Area Manager, describes a spillage of metal oxide that occurred on January 25, 1956. It states that the Plants [[redacted]] foremen were notified, and that a total of 2,700 pounds of metal oxide had been sent to the silo on the third shift.

We are also concerned that since Silo 3 did not contain uranium in significant quantities, it is not apparent how NIOSH can derive Th-230 intakes from uranium bioassay results for workers who performed operations related to Silo 3 material.

3.0 CONCLUSIONS

- It does not appear to be possible to assign Th-230 bounding intakes based on uranium bioassay results to workers that performed their jobs in the raffinate areas of Plant 3 and in Silos 1, 2 or 3, where exposures to uranium were insignificant. The DWAs given in Appendix A of the White Paper were used to demonstrate that in Plant 3 raffinate areas, the exposure levels were low and *should be considered ambient levels.* NIOSH used the DWAs results to justify discarding exposures that occurred in those areas. This justification is questionable, because the DWAs in Appendix A of the White Paper are an incomplete set of DWAs. Other data on air concentrations taken in the Plant 3 raffinate area have shown much higher exposures. In addition, GA measurement results carry significant uncertainties in relation to the workers' real exposures. No data or analyses were provided to justify discarding Th-230 exposures in Silos 1, 2 and 3 areas.

- For workers that performed their jobs in areas of mixed exposure to uranium and uranium daughters, it is necessary to know if the workers could have been exposed in the raffinate areas and in Silos 1, 2 or 3, as well. Bounding intakes of thorium can only be assigned to those workers if there was no job assignment in the raffinate and silos areas.

- SC&A has concerns on the assignment of thorium intakes that are equal to the intake of U-234 or U-238 in natural uranium determined in mass units, based on reviews of DWA in Plants 2 and 3 (Period 1953–1970). For workers that performed their jobs only or mainly in areas of mixed exposure to uranium and daughters, the DWA data used to justify the chosen ratio of Th-230/U-238 concentrations in air are incomplete, and the assumption is not claimant favorable.

- DWA data represent typical, rather than bounding, exposures. NIOSH needs to develop bounding exposure values for Th-230 in the SEC context.

- SC&A has concerns on the assignment of thorium intakes that are equal to 10% of the intake of U-234 or U-238 in natural uranium, determined in mass unit, in the period 1970–1989, for workers that only performed their jobs in areas of mixed exposure to uranium and daughters. NIOSH did not present a detailed analysis for this conclusion, and there is no scientific calculation to demonstrate the validity of the assigned ratio of Th-230/U-238 intakes.

REFERENCES

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