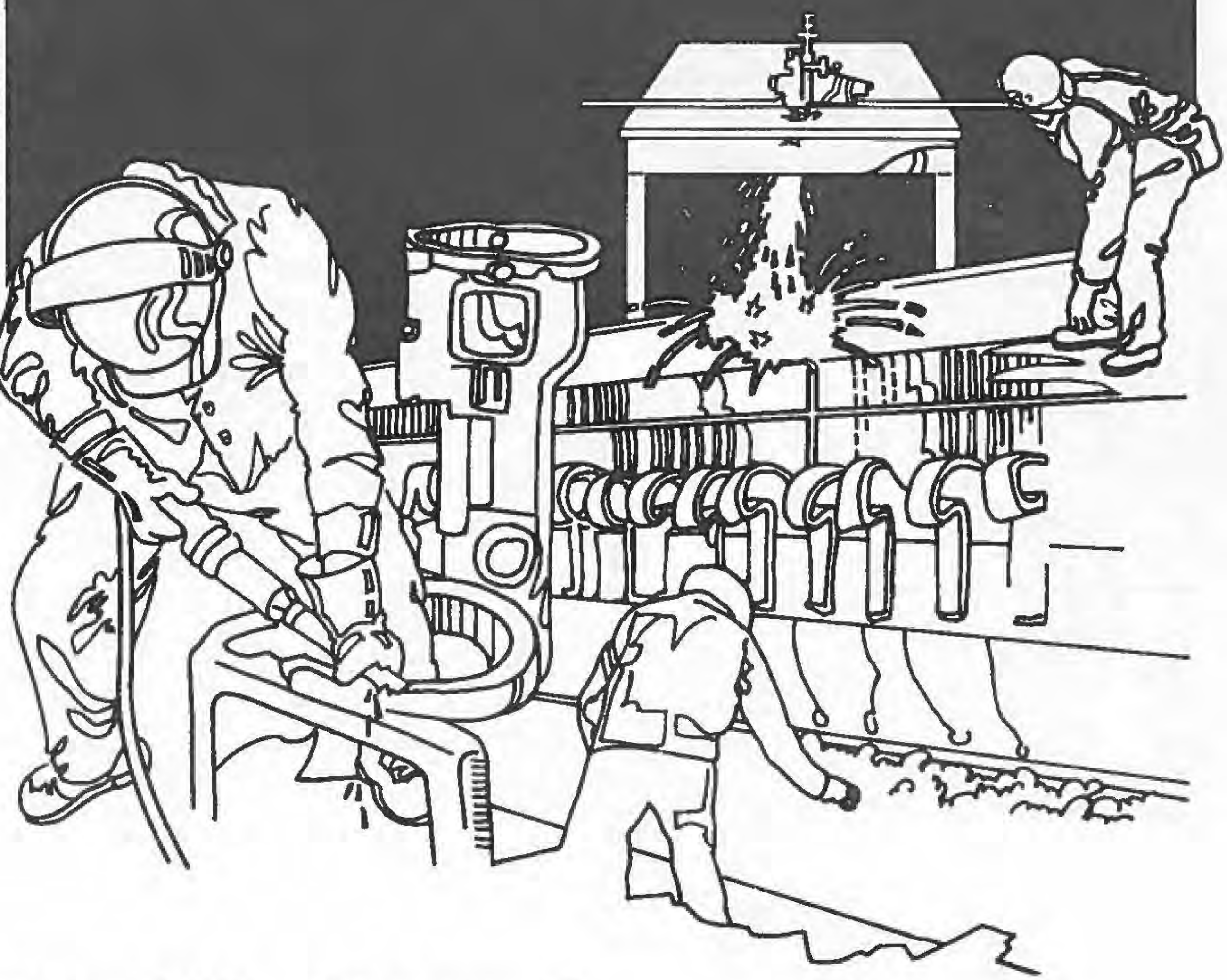
U.S. DEPARTMENT OF HEALTH AND HUMAN SERVICES ■ Public Health Service
Centers for Disease Control ■ National Institute for Occupational Safety and Health

NIOSH



# Health Hazard Evaluation Report

HETA 83-144-2001
FEED MATERIALS PRODUCTION CENTER
(WESTINGHOUSE MATERIALS COMPANY OF OHIO)
FERNALD, OHIO

## PREFACE

The Hazard Evaluations and Technical Assistance Branch of NIOSH conducts field investigations of possible health hazards in the workplace. These investigations are conducted under the authority of Section 20(a)(6) of the Occupational Safety and Health Act of 1970, 29 U.S.C. 669(a)(6) which authorizes the Secretary of Health and Human Services, following a written request from any employer or authorized representative of employees, to determine whether any substance normally found in the place of employment has potentially toxic effects in such concentrations as used or found.

The Hazard Evaluations and Technical Assistance Branch also provides, upon request, medical, nursing, and industrial hygiene technical and consultative assistance (TA) to Federal, state, and local agencies; labor; industry and other groups or individuals to control occupational health hazards and to prevent related trauma and disease.

HETA 83-144-2001
DECEMBER 1989
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## I. SUMMARY

In February 1983, the National Institute for Occupational Safety and Health (NIOSH) received a request from District 34, International Association of Machinists for an assessment of potential exposures and possible health effects from radiologic and chemical contamination within the Feed Materials Production Center (FMPC), Fernald, Ohio. This facility is owned by the U.S. Department of Energy (DOE), and was operated at the time of the request by National Lead of Ohio, Inc. Since January 1, 1986, it has been operated by Westinghouse Materials Company of Ohio (WMCO).

In September 1985, NIOSH investigators conducted a cross-sectional medical study of FMPC workers, including evaluation for evidence of lung and kidney disease attributable to uranium exposure. Although this study had some limitations, there were associations between respiratory effects and indicators of uranium exposure. The ratio of the 1-second forced expiratory volume to the forced vital capacity ($FEV_1$/FVC) was associated with a job history-derived uranium exposure index, even after accounting for cigarette smoking, and shortness of breath was associated with self-reported uranium exposure incidents. No association was identified between uranium exposure and renal damage or dysfunction.

In December 1987, NIOSH investigators measured surface alpha particle radiation contamination at about 50 selected worksites within the facility's chemical and machining plants. With one exception, levels of alpha particle radiation exceeded the limit specified by WMCO for process areas [5000 disintegrations per minute (dpm) per 100 square centimeters]. Furthermore, review of the dispensary log indicated a disproportionately large number of laceration/contusion injuries, thus affording a more effective route of exposure from the contaminated surfaces. NIOSH investigators also measured employee exposures to chemical and radiologic air contaminants within the plants. Environmental air samples were collected for total fluorides, nitric acid, nitrogen dioxide, hydrofluoric acid, ammonia, graphite dust, and oil mist. Nitrogen dioxide was the only chemical air contaminant exceeding current applicable occupational health criteria. Radiologic air samples were collected for gross alpha and beta concentrations. None were in excess of the DOE-derived guidelines for occupational exposure to these substances.

Based on the environmental sampling results and review of the pertinent FMPC industrial hygiene and radiologic health programs, the NIOSH investigators conclude that at the time of this survey a potential health hazard existed due to excessive levels of surface alpha particle contamination. Improvements are needed to eliminate this contamination and to maintain exposure to uranium at the lowest feasible level. Recommendations to reduce potential exposures are presented in Section VIII of this report.

KEYWORDS: SIC 2819 (Industrial Inorganic Chemicals), uranium, radiation, plutonium.

## II. INTRODUCTION

In February 1983, the National Institute for Occupational Safety and Health (NIOSH) received a request for a health hazard evaluation from District 34, International Association of Machinists, to evaluate the Feed Materials Production Center (FMPC), Fernald, Ohio. The plant is owned by the U.S. Department of Energy (DOE), and was operated at the time of the request by National Lead of Ohio., Inc, (NLO). Since January 1, 1986, it has been operated by Westinghouse Materials Company of Ohio (WMCO). The requestor and other union representatives expressed concern about a number of health problems which they associated with their workplace, resulting from radiologic and chemical exposures, and requested that NIOSH conduct a medical and environmental assessment.

Following a walk-through inspection of the facility in October 1983, NIOSH investigators focused the medical component of the hazard evaluation on screening workers for evidence of lung and kidney disease attributable to uranium exposure. The medical evaluation was delayed until September 1985, because of extensive administrative procedures required by DOE to allow NIOSH access to pertinent employee medical and personnel records. Results of the medical study (appendices A and B) were provided to representatives of WMCO, DOE, labor unions, and other interested parties in July 1987 and June 1988.

In December 1984, the Director of Health, State of Ohio (on behalf of the FMPC workers) requested that NIOSH assess potential health effects among FMPC workers following releases of uranium oxide from dust collectors in Plant 9. These releases occurred between November and December 1984. The results of this study were reported in a final report dated January 1987.[3]

In May and December 1987, NIOSH conducted the environmental component of the current health hazard evaluation (HETA 83-144). This evaluation involved assessment of the current chemical and radiologic exposures. Preliminary results and recommendations from this investigation were disseminated in March, 1988.[4]

## III. BACKGROUND

The FMPC, Fernald, Ohio, is an older, large-scale, integrated uranium metals production facility which converts a variety of chemical forms of depleted or slightly (1-2%) enriched uranium into uranium metal. The uranium metal produced at this facility is used in fuel cores for DOE-operated reactors and in nuclear weapons. FMPC started production in 1953 and since that time the facility has been contractor-operated for DOE. The land, buildings, fixtures, and equipment at FMPC is owned by DOE. Funding for present FMPC operations is provided by DOE, including salaries/wages, procurement of equipment, materials, and capital expenditures. The actual production area at FMPC covers 136 acres of the total 1050 acres at the site. At the time of this evaluation, Westinghouse Materials Company of Ohio (WMCO) operated the facility with an hourly workforce of approximately 850 workers in the production plants.

Production of uranium (U) metal requires a number of chemical and metallurgical processes located in several production buildings, or "plants". A schematic diagram of the FMPC process is provided in Figure 1. The chemical processes are predominately closed-system, batch-type operations utilizing equipment similar to that found in chemical manufacturing plants. Since the uranium production process at this facility is batch-oriented, chemical exposures are more likely to occur at the beginning or end of a particular batch operation, when raw materials or products are handled, or during ancillary operations. Certain operations were idle for extended periods because of the periodic nature of the process. A listing of raw materials, products, and major processes for each of the major production plants follows:

| Plant | Raw materials; Products | Processes |
|---|---|---|
| Plant 1 | Various U-bearing feed materials | Assaying/classifying of feed materials |
| Plant 2&3 | Uranyl nitrate; $UO_3$ | Digestion, extraction, denitration |
| Plant 4 | $UO_3$; $UF_6$ | Conversion of $UO_3$ to $UF_6$ |
| Plant 5 | $UF_4$, magnesium metal; U metal | Conversion of $UF_4$ to U metal |
| Plant 6 | U metal | Machining, acid pickling |
| Plant 8 | Various U-bearing scrap materials | Scrap recovery |
| Plant 9 | U metal | Machining, acid pickling |
| Pilot Plant | $UF_6$; $UF_4$ | Reduction of $UF_6$ to $UF_4$ |

Four methods are used by WMCO to document a worker's radiation exposure. Each worker who is classified as a radiation worker wears a a thermoluminescent dosimeter (TLD) on a monthly basis to record external beta-gamma radiation exposure. These badges are collected and processed monthly to determine worker's exposure. Also, a mobile radiation whole body (WBC) counter visits FMPC about twice a year. Details on this method have been previously discussed in a NIOSH report.[3] However, not all workers are evaluated with this method; only those that work in management-defined potentially hazardous areas. At present WMCO is installing a permanent state-of-the-art whole body counter. A weekly or monthly urine sample may also be collected from selected workers. The use of such samples can indicate possible uptake of radioactive material into exposed workers. The final method to document radiation exposure involves collection of daily general area air samples for determination of gross alpha and beta radiation exposures associated with airborne uranium.

## IV. EVALUATION METHODS AND MATERIALS

In an initial assessment of radiologic exposures, records of worker exposure data were obtained from TLD badges, whole body counts, and urine samples. Other pertinent information was derived from discussions with representatives of WMCO, DOE, and employee representatives.

On December 2 and 3, 1987, NIOSH investigators made approximately 50 surface measurements for alpha particle contamination from locations within all seven chemical and machining plants. A Ludlum Model 12 radiation monitoring instrument equipped with a Model 43-5 alpha probe was used; the detector was held approximately 1/2 inch from the surface being tested. The instrument had recently been calibrated by the manufacturer, and was checked by WMCO Health and Safety personnel according to their procedures.

On December 3, 1987, 14 general area radiological air samples were collected for gross alpha and beta radiation concentrations. Three of the 14 samples were also analyzed for isotopic uranium. Sampling sites were selected within the seven production plants by NIOSH investigators based on their judgement as to the greatest potential for radiation exposure. Air monitoring equipment routinely used by WMCO was employed by NIOSH, with air flow rates set in consultation with WMCO personnel. The sampling equipment was positioned approximately 4 feet off the floor facing the direction considered to represent a potential inhalation route. Samples were analyzed under contract with a certified radiological counting facility.

Also on December 2 and 3, 1987, NIOSH investigators collected 41 personal breathing zone (PBZ) and 6 general area air samples to assess worker exposure to selected air contaminants including particulate and gaseous fluorides, nitric acid ($HNO_3$), nitrogen dioxide ($NO_2$), hydrofluoric acid (HF), ammonia ($NH_3$), graphite dust, and oil mist. These samples were collected in seven of the chemical and machining plants during first shift operations. Most were collected over a full workshift; partial shift samples were collected for those processes which did not operate for an entire shift. A listing of job classifications/plant areas, air contaminants, and operations is provided in Table 1. Sampling and analytical methods used by NIOSH and WMCO ("side-by-side" samples collected by WMCO), along with other pertinent data, are presented in Table 2.

A limited qualitative assessment of local exhaust ventilation (LEV) systems servicing equipment operated by workers who were monitored for chemical exposure was performed. This was accomplished by observing air currents visualized by smoke generated from smoke tubes and by use of a NIOSH calibrated thermal anemometer.

## V. EVALUATION CRITERIA

### A. Radiation Exposure

In 1960 the Federal Radiation Council directed all federal agencies to adopt a radiation exposure policy which would ensure that radiation workers' exposures are reduced to the lowest practical level. This policy has come to be known by the acronym ALARA (as low as reasonably achievable). The ALARA requirements for DOE are found in DOE Order 5480.1. [5] This order does not spell out specific methods for contractors to meet the ALARA exposure level, but it does provide general guidance information in such areas as plant/equipment design, regular inspections, and monitoring procedures. The radiation exposure limits for DOE are shown in Table 3. In addition, WMCO has established administrative dose controls (ADC) at levels well below DOE limits to ensure compliance with ALARA.

### B. Chemical Exposures

As a guide to the evaluation of the health hazards posed by workplace exposures, NIOSH field staff employ environmental exposure criteria for assessment of a number of chemical and physical agents. These criteria are intended to suggest levels of exposure to which most workers may be exposed up to 10 hours per day, 40 hours per week for a working lifetime without experiencing adverse health effects. It is, however, important to note that not all workers will be protected from adverse health effects if their exposures are maintained below these levels. A small percentage may experience adverse health effects because of individual susceptibility, a preexisting medical condition, and/or a hypersensitivity (allergy).

In addition, some hazardous substances may act in combination with other workplace exposures, the general environment, or with medications or personal habits of the worker to produce health effects even if occupational exposures are controlled at the level set by the evaluation criterion. These combined effects are not often considered in the evaluation criteria. Also, some substances are absorbed by direct contact with the skin and mucous membranes, and thus increase the overall exposure. Finally, evaluation criteria may change over the years as new information on the toxic effects of an agent become available.

The primary sources of environmental evaluation criteria for the workplace are: (1) NIOSH Criteria Documents and Recommended Exposure Limits (RELs) [6], (2) the American Conference of Governmental Industrial Hygienists' (ACGIH) Threshold Limit Values (TLVs) [7], and 3) the U.S. Department of Labor (OSHA) Permissible Exposure Limits (PELs) [8]. Often, the NIOSH RELs and ACGIH TLVs are lower than the corresponding OSHA PELs. Both NIOSH criteria and ACGIH TLVs usually are based on more current information than are the OSHA PELs. The OSHA PELs also may be required to take into account the feasibility of controlling exposures in various industries where the agents are used; the NIOSH RELs, by contrast, are based primarily on concerns relating to the prevention of occupational disease.

A time-weighted average (TWA) exposure refers to the average airborne concentration of a substance during a normal 8- to 10-hour workday. Some substances have recommended short-term exposure limits or ceiling values which are intended to supplement the TWA where there are recognized toxic effects from high short-term exposures.

A list of the sampled substances and their applicable environmental criteria are presented in Table 4, along with a brief description of their primary health effects.

## VI. RESULTS AND DISCUSSION

### A. Radiological Considerations

#### 1. Surface Radiation Contamination Levels

About 50 surface sites throughout the entire facility were sampled to determine alpha particle contamination. Most areas tested were sites where workers would typically be located. The limits for removable surface contamination, as published in the WMCO Radiation Control Manual [9], are 5000 disintegrations per minute (dpm)/100 $cm^2$ for clean (other surface) areas. This criteria was used to determine if excess surface contamination was present. Virtually all surfaces tested exceeded the criteria, regardless of building and specific location. For example, typical contamination levels in Plants 2 and 3 were around 30,000 dpm/100 $cm^2$ and in Plant 4, approximately 25,000 dpm/100 $cm^2$. The only exception was in the Pilot Plant where levels were on the order of 1000 dpm/100 $cm^2$.

Excessive alpha particle surface contamination within the facility has been known to exist at least since January 1986, when WMCO took over operations from NLO. At that time, WMCO produced a phase-in report under a DOE contract.[10] The following was excerpted from Volume 4 of this report.

"There were several areas observed throughout the plant facilities where engineered changes or automation would reduce the risk of hand injuries and also reduce the risk of contamination becoming airborne. Many of these fixes are in the planning stages at this time.... Break areas throughout the plant have been surveyed for contamination. Many of these areas are in excess of DOE 5480-1 Chapter XI guidelines and are in the need of cleaning and more rigorous monitoring. An evaluation of all break area locations is needed and perhaps some may need to be relocated....In accordance with DOE criteria, more rigorous controls need to be maintained in this facility....A survey sheet of the break area (in Plant 1) in the area of this operation indicated excessive contamination was present......"

NIOSH findings of alpha particle surface contamination above the DOE limits, not only in a break room but in many other plant locations, indicates non-compliance with DOE standards.

2. TLD Analysis

A Government Accounting Office (GAO) report [11] stated that in past years there have been occasions where whole body radiation exposures have exceeded standard levels. However, in recent years, no employee has reportedly received an annual whole body radiation exposure greater than 2 rems. A review of FMPC TLD records indicated that whole body radiation exposures for WMCO personnel during the last 4 years have not exceeded the annual maximum permissable exposure (MPE) limit of 5 rems (Table 5). Approximately one-third of the workforce in 1987 did not receive any whole body radiation exposure and slightly less than two-thirds of the same workforce received less than 1 rem. However, for skin exposure there were in excess of 250 workers who received more than two rems annually (1984 - 1987). Table 5 shows that some workers have exposures higher than 10 rems annually. Table 6 presents estimates made by WMCO for high potential exposure jobs in Plant 5 as of July 1987. The table confirms that at WMCO it is the skin, and not whole body exposure, that represents the largest component of measured radiation exposure. When the values in the table are projected over a 50-week year, they suggest skin exposure levels as high as 20.5 rems and whole body exposure on the order of 2 rems.

In addition to TLD badges, designated personnel in Plants 5, 9, and the Pilot Plant, as well as ES&H personnel, are required to wear wrist dosimeter badges during work. These wrist badges are used to estimate the radiation exposure to the forearms and hands.[12] No records for this type of exposure were received by NIOSH from WMCO and therefore are not addressed in this report.

3. Radiologic Air Sample Analysis

Results from the side-by-side NIOSH and WMCO plant-wide radiologic air samples showed that on the day of measurement none were in excess of the DOE derived concentration guidelines for occupational exposure to airborne radioactive contaminants (Table 7). The NIOSH and WMCO alpha radiation results are similar considering the manner in which they were collected and that in several instances for unexplained reasons, the air sample collection devices had been moved or altered during the test period. The largest difference for the alpha radiation samples was noted in the data from the Pilot Plant and Plants 2-3. The results for beta radiation are also similar except for the two areas mentioned above, and for sample 5E. The difference between the results was almost three orders of magnitude. No explanation is offered for the difference. Unfortunately, one of the sample filters (5C) was lost by WMCO and comparisons are not possible.

None of these side-by-side results exceeded the maximum levels reported by WMCO for the first seven months of 1987 (Table 8).

4. Urine Uranium Levels

The previous NIOSH investigation [1] suggests that current uranium exposures are within currently acceptable limits for occupationally exposed individuals.

5. Plutonium-Out-Of-Specification (POOS) Findings

POOS is defined by WMCO officials as material having more than 10 parts per billion (ppb) concentration of plutonium. According to a WMCO publication [13] POOS material was still being processed as late as June 30, 1987 and POOS material was not scheduled to be flushed from the feeder system until December 1987.

The GAO report [11], revealed that POOS materials having levels as high as 7757 ppb were found on the Fernald site. This finding by a 1985 DOE task force also revealed that processed POOS levels were not documented properly. This meant, according to GAO, that DOE could not determine worker exposure.

On November 11, 1986, production at Plant 4 was stopped after "uranium trioxide containing trace amounts of plutonium spilled from an automatic feeder system onto the floor". [13]

At the request of NIOSH, DOE forwarded a chronology of major events dealing with processing POOS material. This chronology, developed by WMCO personnel, is detailed in Appendix C. At the time of this evaluation, but after our December 1987 site visit, several workers were in the process of undergoing whole body counting for possible plutonium inhalation. NIOSH has been informed, both by DOE and WMCO safety personnel, that the counting results from these workers indicated that none of the selected production plant personnel monitored were at risk to plutonium exposure.

A December 1988 WMCO letter to a FMPC chemical worker suspected of plutonium uptake, states that his uptake around August 1986 resulted in an effective dose of 26 millirems in the first year and 17 millirems in the second year. These exposures are included in the worker's exposure history. [14] Our investigation did not examine in detail the past use of POOS material in the plant.

B. Chemical Agents/Industrial Hygiene

1. Review of Dispensary Log and Industrial Hygiene Monitoring Data

WMCO's industrial hygiene air sampling data (covering the period from January 1986 to June 1987) revealed that 2,250 air samples were collected plantwide (excluding those for oxygen deficiency) for approximately 35 chemical contaminants. Most (75%) of the samples were of the general area type while the remaining air samples were PBZ. The most commonly sampled contaminants included hydrogen fluoride, particulate fluorides, carbon monoxide, hydrogen sulfide, and asbestos. (Sampling for asbestos is conducted during abatement or high level cleaning activities and written procedures have been developed for WMCO employees and/or subcontractor personnel who may work with asbestos). Exposures in excess of current occupational health standards were not reported in any of the PBZ samples. We did note that extrapolated 8-hour TWA concentrations reported for the PBZ samples were low (always by a factor of 10) when compared to the TWA concentration reported for the sampling period. This apparent systematic error was reported to WMCO industrial hygiene personnel and the necessary corrections in their computer records were made.

Review of WMCO's 'Daily Log of Occupational Injuries' records revealed that during an 18 month period from January 1986 through June 1987 there were 807 injuries/illnesses reported by workers. (This number does not include revisits made to the dispensary, just initial visits). Of these, only 9 (1.1%) were attributable to inhalation of a chemical agent. Those chemical agents identified by workers included HF, ammonia, magnesium fluoride, and uranium tetrafluoride (green salt). Also reported were 17 skin burn and/or eye irritation cases resulting from contact with acids or caustics, one case of dermatitis associated with lubricating oil contact, and one case of possible uranium ingestion. The remaining 779 (96%) cases consisted of contusions and/or lacerations. Although many of these injuries did not involve lost work-time, the high number of contusions and/or lacerations reported poses a potential occupational route of entry of radioactive (and chemical) materials.

2. Air Sampling Data

During the two-day environmental evaluation, 41 PBZ and 6 area air samples were collected to assess worker exposure to selected air contaminants in seven of the chemical and machining plants during first shift production operations. All of the air sampling results represent TWA's over the sampling period. They are presented in Tables 9 to 15 by plant site, beginning with Plant 1 and then proceeding in numerical order up to the Pilot Plant. Corresponding WMCO air sampling results are also presented in these Tables.

a. Sampling Plant (Plant 1)

Four Sampling Plant workers were monitored for exposure to total (particulate and gaseous) fluorides (Table 9). Two of the workers were monitored during drum sampling operations and had exposures of 0.01 and 0.005 mg/m$^3$. A mill operator and slag drummer were monitored while cleaning drums of assayed uranium-bearing material (the milling and drumming operations were idle). Total fluoride concentrations were 0.006 and 0.02 mg/m$^3$ respectively. Fluorides were present in three of four samples exclusively as particulate. The measured concentrations were well below the evaluation criteria of 2.5 mg/m$^3$ for total fluorides. The total fluoride content in these samples may be somewhat higher than reported because the untreated back-up pad (which may also trap gaseous fluorides) was not analyzed (see Appendix D for further discussion).

b. Metal Dissolver Plant (Plant 2)

The environmental sampling results for Plant 2 are presented in Table 10. Sampling was limited to the extraction process since the digestion and denitration processes were idle during this evaluation. Two PBZ samples and one area air sample were collected for nitric acid and nitrogen dioxide. The two PBZ samples were obtained from extraction operators who were primarily responsible for monitoring control panels along the main floor, checking the uranyl nitrate feed tanks in the digestion area, and collecting samples of uranyl nitrate for assay. Nitric acid exposures were similar for the two operators, measuring 0.06 and 0.07 mg/m$^3$, and were below the evaluation criteria of 5.0 $mg/m^3$. Nitrogen dioxide was detected in one of the PBZ samples at a concentration of 0.17 $mg/m^3$ which was below the evaluation criteria of 1.8 $mg/m^3$; the sample from the other extraction operator, although nondetectable (ND), was judged to be invalid (see note B on Table 10). Given that the work activities of the extraction operators were similar, exposure of the worker with the invalid sample was probably not significantly different than that of his colleague. Concentrations of nitric acid and nitrogen dioxide at the uranyl nitrate feed tanks in the digestion area measured 0.34 and 0.60 $mg/m^3$, respectively.

c. Green Salt Plant (Plant 4)

Environmental sampling results for Plant 4 are presented in Table 11. Air samples were collected from three workers for hydrogen fluoride (HF) and/or ammonia. An area sample was also collected from the north end of Plant 4 where the ammonia dissociators are located. The tank farm operator was monitored for both HF and ammonia. The talcum reactor operator and the drum station/main panel board operator were only monitored for HF since there was no potential for exposure to ammonia in these operations. HF was not detected in any of the PBZ samples collected by NIOSH; the environmental limit of detection was calculated to be no greater than 0.03 $mg/m^3$ based on the lowest sample air volume.

The concentration of ammonia in the immediate vicinity of the ammonia dissociators was relatively low, measuring 2.2 $mg/m^3$.

d. Metals Production Plant (Plant 5)

Table 12 presents the air sampling results for Plant 5. Eight workers were monitored for total (particulate and gaseous) fluorides while engaged in various uranium melting and casting operations. Total fluoride concentrations ranged from 0.02 to 0.20 $mg/m^3$ and were well below the evaluation criteria of 2.5 $mg/m^3$. The total fluoride levels of these samples are probably somewhat higher than reported for the same reason described earlier (see Appendix D). However, because the operations evaluated are more likely to liberate particulate rather than gaseous fluorides, exposure to total fluorides above the evaluation criteria at the time of our survey was very unlikely.

Three air samples, including two PBZ samples from graphite machinists and one area sample from the machining room were collected and analyzed for graphite (as total dust).

Graphite concentrations for the two PBZ samples measured 0.35 and 0.58 mg/m$^3$; the area sample measured 0.18 mg/m$^3$ (Table 12). All three samples were below the evaluation criterion of 10 mg/m$^3$ for nuisance particulates.

e. <u>Metals Fabrication Plant (Plant 6)</u>

Table 13 presents the air sampling results for Plant 6. Two PBZ samples and one area sample were collected to assess worker exposure to nitric acid mist and nitrogen dioxide ($NO_2$). Potential exposure to these contaminants resulted from the use of nitric acid in two pickling operations (chip and scrap) and from its use in the sump treatment room to treat, via a closed system process, waste water from Plants 5 and 6.

Nitric acid and $NO_2$ concentrations from the chip pickling tank operator measured 1.01 and 1.88 mg/m$^3$, respectively. Although the concentration of nitric acid was within the evaluation criterion of 5 mg/m$^3$, the $NO_2$ level measured by NIOSH in the PBZ of the chip pickling tank operator slightly exceeded the REL of 1.8 mg/m$^3$. The chip pickling tank operator's exposure to a concentration of $NO_2$ in excess of the NIOSH REL was unexpected, since this pickling process was not operating, due to a problem with the conveyor motor. It should be noted that even though uranium-bearing chips were not being loaded into the tanks, $NO_2$ can still be liberated from the ventilated nitric acid tank. At the time samples were collected it was unclear whether the chip pickling tank operator's exposure was representative of normal operations. Given the questionable nature of the data, WMCO subsequently collected samples on March 15-25, 1988, for $NO_2$, as well as nitric oxide and nitric acid, during a time when the pickling process was operational. According to their results [15], air levels of these two substances were below their respective, most stringent environmental criteria.

While treating depleted uranium metal flats, the scrap pickling tank operator was exposed to nitric acid and $NO_2$ concentrations of 1.0 and 0.11 mg/m$^3$, well below their respective most stringent environmental criteria. Low levels of nitric acid and $NO_2$ were also measured in the sump treatment room.

Four PBZ samples were collected from mill operators for oil mist while flats of depleted uranium were machined. A water-soluble coolant, diluted 1:50, was used at each of the mills where workers were monitored. Oil mist concentrations for these four air samples ranged from 0.07 to 0.09 mg/m$^3$ and were well below the evaluation criteria of 5 mg/m$^3$.

f. Special Products Plant (Plant 9)

Table 14 presents the air sampling results for Plant 9. Four milling machine operators and the Zirnlo operator were monitored. The milling machine operators were monitored for oil mist. The 4L and 5L lathes utilize the same water-soluble coolant used on the milling machines monitored in Plant 6. The rapid borer machine uses a petroleum oil/additive blend. Oil mist concentrations for the lathe operators ranged from 0.17 to 0.45 $mg/m^3$, while a level of 0.10 $mg/m^3$ was measured for the rapid borer operator. All oil mist concentrations were well below the evaluation criteria of 5 $mg/m^3$.

The Zirnlo operator was monitored for nitric acid and $NO_2$ during pickling of uranium metal derbies. Chemical decladding of derbies utilizing hydrofluoric acid is also performed at the Zirnlo workstation potentially exposing workers to HF. However, at the time of this survey, derbies requiring this particular treatment were not scheduled. Breathing zone concentrations of nitric acid and $NO_2$ were 0.05 and 0.37 $mg/m^3$ respectively, during the approximately 3 hour task. These levels were well below the evaluation criteria for both substances.

g. Pilot Plant (Plant 37)

Air sampling results for the Pilot Plant are presented in Table 15. Two workers, the uranium tetrafluoride (green salt) drum packout operator and the utility man (primarily responsible for hooking up cylinders of uranium hexafluoride, checking equipment for leaks, and monitoring the process from the control room) were evaluated for total (particulate and gaseous) fluorides and HF. Total fluoride levels for these two workers measured 0.008 and 0.001 $mg/m^3$, respectively, and were well below the evaluation criteria of 2.5 $mg/m^3$ for total fluorides. HF was not detected in either air sample collected by NIOSH.

An area sample placed at the ammonia dissociators (an outdoor installation) measured ammonia at a concentration of 0.6 $mg/m^3$, well below the evaluation criteria of 18 $mg/m^3$.

The environmental sampling results show that workers were not exposed to excessive levels of any of the chemical substances sampled during this survey. Although our air monitoring efforts did not encompass the entire spectrum of potential chemical exposures at FMPC, they nevertheless are in general agreement with the information contained in WMCO's industrial hygiene air sampling and dispensary log records which show that worker exposure to chemical agents were relatively low during the 18 month period covered by our records review.

Comparison of the paired NIOSH and WMCO air sampling results for chemical contaminants were all within an order of magnitude of each other.

During this evaluation NIOSH industrial hygienists observed deficiencies in some of the methods used to control worker exposures. Deficiencies were noted in some of the local exhaust ventilation systems evaluated and, although they did not result in any overexposures, corrective measures were recommended (see Appendix E) with the intent of reducing exposure as low as reasonably achievable.

C. Ventilation

A limited qualitative assessment of local exhaust ventilation (LEV) systems servicing equipment operated by workers who were monitored for chemical exposure was conducted. Our evaluation included the LEV systems servicing the drum sampling line in Plant 1; the #1 and #2 uranium tetrafluoride ($UF_4$) drumming operations in Plant 4; the bottom and top F machines (with the exception of the LEV systems for the #4 and 5 top F machines which were down for repairs), capping machines, slag breakout operations, and the graphite lathes and table saws in Plant 5; the Versi and K&T milling machines and the scrap pickling tank in Plant 6; and the 4 and 5L lathes in Plant 9.

The ventilation assessment revealed that most of the LEV systems evaluated were operating satisfactorily (i.e., sufficient capture velocity to contain airborne contaminants) at the time of our evaluation. For some operations, deficiencies such as inadequate duct air velocity (graphite lathes, Plant 5) or air current interferences associated with nearby makeup air units (green salt drumming station #1, Plant 4) were noted. We also observed work practices which compromised the effectiveness of some well designed ventilated enclosures (reactor pot enclosures, Plant 5). Specific operations where improvements could be made are presented in Appendix E.

D. Observations

Improper storage of respirators was observed in Plants 4 and 5. Apart from reducing the service life of chemical cartridges, this unacceptable practice may result in the inadvertent ingestion of radiation contaminated materials, given the documented contamination problem.

As discussed and detailed in a previous NIOSH study,[3] DOE needs to address the overall accuracy and reproducibility associated with WBCs, and a cross-validation program for all operating DOE whole body counters should be implemented.

There were several noted instances where relocation of desks, work stations, equipment, and walkways would have reduced the beta radiation exposure component. We also observed that beta radiation shielding material, such as steel or aluminum sheet metal, rubber matting, or thick plastic sheeting, was not always used.

Our discussions with workers revealed that some plant supervisors, whose primary responsibilities are to assure acceptable production levels, were also charged with administering safety and health practices. Because of conflicting demands on their time, supervisors are sometimes having to choose between their assigned duties. Other supervisors with responsiblity for specific activities, such as decontamination operations, were having radiation control functions added to their work load. Supervisors who are being asked to perform too many functions are not able to give the proper attention to their radiation control functions.

A major radiation control measure being implemented at the time of our investigation was the development of a radiation monitoring data base management system called "Flow Gemini". When this system is fully operational it should greatly enhance the environmental, chemical, and radiological safety management issues within WMCO. Hopefully, such a system will also permit workers to obtain their complete radiation exposure profile with minimal delay.

Better control is needed for access and egress from restricted areas. To enter a plant production area, authorized personnel must first enter a restricted access area to change cloths. During the transition from the non-restricted to restricted area workers are required to don protective smocks, shoe covers, hardhats, TLD badges, and perhaps hearing protectors. We observed many infractions of acceptable health physics practices within the access areas, near the mens and visitors locker room, including protective smocks and shoe covers spread over the floor and not confined to the designated smock and shoe containers, TLD badges placed on lockers, sinks, floors, and tables rather than on the designated TLD badge holder, workers not monitoring themselves with the hand and foot radiation meters in the transition area, and the presence of holes in the protective mat in the transition area permitting contamination to occur on both sides of the transition area. Comments made to WMCO ES&H personnel resulted in immediate attention given to this matter, but it underscores the problem of maintaining minimal contamination levels within the plant area.

In an annual report [15] which WMCO is required to submit to DOE, mention is made that WMCO was able to reduce the "normalized penetrating/non-penetrating doses" which met an ALARA milestone. The concept of "normalized doses" raises some basic radiation safety issues. Because more work was done with uranium requiring additional manhours, the normalized dose (reported radiation dose divided by product of increased uranium use and increase in manhours) was reduced. In reality, however, the dose increased. ALARA should be achieved by reducing the time of exposure or decreasing the radiation levels in the working environment, not by diluting with more people. The use of the term "normalized dose" seems to be an artifical method used to administratively explain a higher cumulative dose due to emphasis placed on job productivity requirements rather than adherence to the ALARA concept.

The Health and Safety radiologic health technicians were observed smoking,.drinking, and eating while handling radiological samples. When the NIOSH investigator queried them about this practice he was told that the smoke gets worse when more people are in the counting room. In fact, a fan had to be installed to disperse the smoke. This demonstrates a serious disregard for WMCO's own policies put forth in their radiation control manual. In addition, improvement of quality control in the counting room can be made with the use of automated data acquisition printing systems rather than by using manual data transcribing techniques.

E. Summary Of Medical Study

The medical study included a medical and occupational history questionnaire, urine and blood tests for several indicators of renal function and damage, a chest X-ray, pulmonary function tests, and determination of uranium concentration in a post-shift urine sample. Company personnel records and urine uranium monitoring data were used to construct work and exposure histories. Indicators of uranium exposure included self-reported uranium exposure "incidents", an index of cumulative exposure based on the job history, and two different summary estimates of cumulative exposure based solely on the historic urine uranium data.

One hundred forty-six (70%) of 208 eligible long-term employees participated in the study. They had worked at the FMPC from 10 to 34 years, with a median of 32. The 118 urine uranium concentrations measured during the NIOSH survey were all less than 15 micrograms per liter (ug/l), an action level recommended by the U.S. Nuclear Regulatory Commission; 109 were less than 5 ug/l, the laboratory's limit of detection.

The study demonstrated some associations between respiratory effects and indicators of uranium exposure. The ratio of the 1-second forced expiratory volume to the forced vital capacity ($FEV_1$/FVC) was associated with the job history-derived uranium exposure index, even after accounting for cigarette smoking. Shortness of breath was not associated with this exposure index, but was significantly associated with self-reported uranium exposure incidents. Neither chronic cough nor chronic bronchitis was associated with either of these indicators of uranium exposure. None of the 130 X-rays had increased interstitial markings suggestive of pneumoconiosis.

Renal effects were evaluated by treating blood and urine test results as both dichotomous variables (abnormal/normal) and continuous variables. There were no associations between test results and any indicator of uranium exposure. This apparent lack of any exposure-related renal effects might have been due to limitations of the study, including participation bias, recall bias, imperfect measures of uranium exposure, and inadequately sensitive measures of uranium nephrotoxicity.

## VII. CONCLUSIONS

Considerable progress has been made by WMCO to improve and upgrade the health and safety of workers at FMPC. Additional staff have been hired, safety manuals have been written, Standard Operating Procedures (SOPs) have been updated, new equipment has been purchased, plant refurbishing has taken place, a new whole body counter has been installed, and communication among workers and management has improved concerning safety matters. However, the actual daily practice of basic health physics still requires additional attention.

As of September 14, 1987, FMPC had developed a complete radiation control manual. [9] The purpose of the manual is to present specific radiation control policies employed by WMCO in operating FMPC. The completion of this manual was an important step in consolidating and understanding the various control measures to be used under operating conditions.

Our observations of existing plant-wide surface contamination levels, carless activities reported in counting rooms, lack of adherence to published DOE standards on contamination levels, the number of injuries reported on the log in radioactive contamination areas, continued reporting of high beta radiation doses, assignment of radiological responsibilities to production supervisors and inappropriate conditions associated with exchange rooms, underscore the need to improve current basic health physics practices. Previous reports by contractors, DOE, and other government agencies have apparently addressed these deficiencies as well.

## VIII. RECOMMENDATIONS

Preliminary industrial hygiene and radiologic recommendations were provided to WMCO by NIOSH in a March 1988 interim report. The recommendations concerning radiologic health focused on the need to clean-up the plantwide radiation contamination problem. The industrial hygiene recommendations addressed deficiencies observed in methods used to control worker exposure (i.e., local exhaust ventilation, personal protective equipment) and improper work practices. We feel that the industrial hygiene interim recommendations were adequately addressed by WMCO in their reply letter. Accordingly, these preliminary recommendations will not be presented here. The WMCO reply letter is found in Appendix E)). These industrial hygiene recommendations presented in this Section are based on records review not completed at the time of the interim report.

The following additional recommendations relating to industrial hygiene and radiologic practices are made with the goal of further improving occupational health and safety at FMPC:

1. Responses to recommendations #1 and #3 of the NIOSH April 7, 1988 letter should be re-addressed. The corrective actions taken were not clearly explained.

2. Surface contamination by alpha emitters throughout the entire facility should be eliminated. The issue of contamination in the plant raises special concerns about laundry workers.

3. Workers should store their respirators in a clean location when not in use to prevent inadvertent ingestion of radiation contaminated materials.

4. Engineering control measures to minimize exposure to external beta radiation need to be increased. Techniques normally used to accomplish dose reduction in this area involves the use of beta radiation shielding material and relocation of desks, work stations, equipment, and walkways.

5. The high number of injuries (contusions/lacerations) experienced by workers as reported on the dispensary log records during an 18 month period starting January 1986, indicate a lack of attention to safe work practices. Steps need to be taken to identify the determinants of these injuries and make the necessary changes in work practices to avoid such injuries.

6. WMCO should continue to keep workers cognizant of the importance of adhering to good work practices and wearing personal protective equipment in accordance with ALARA. WMCO should conduct training courses on the recently issued radiation control manual.

## IX. REFERENCES

1. National Institute for Occupational Safety and Health. Health Hazard Evaluation No. HETA 83-144 (Report of medical study). Cincinnati, OH: NIOSH, July 1987.

2. National Institute for Occupational Safety and Health. Health Hazard Evaluation No. HETA 83-144 (Letter to [redacted], DOE). Cincinnati, OH: NIOSH, June 22, 1988.

3. National Institute for Occupational Safety and Health. Health Hazard Evaluation No. HETA 85-111-1770. Cincinnati, OH: NIOSH, January 1987.

4. National Institute for Occupational Safety and Health. Health Hazard Evaluation No. 83-144 (Letter to [redacted], WMCO). Cincinnati, OH: NIOSH, March 7, 1988.

5. U.S. Department of Energy Regulations 5480.1, Title 10, Code of Federal Regulations, Part 20.

6. NIOSH Recommendations for Occupational Safety and Health Standards. Morbidity and Mortality Weekly Report Supplement, Vol. 37/ No. S-7, U.S. Department of Health and Human Services, August 26, 1988.

7. American Conference of Governmental Industrial Hygienists. Threshold limit values and biological exposure indices for 1988-89. Cincinnati, Ohio: ACGIH, 1988.

8. Occupational Safety and Health Administration. OSHA safety and health standards, 29 CFR 1910. Occupational Safety and Health Administration, revised 1983.

9. Feed Materials Production Center Radiation Control Manual, Westinghouse Materials Company of Ohio, FMPC-2084, dated September 14, 1987. Prepared for DOE under Contract No. DE-AC05-860R21600.

10. Feed Materials Production Center Final Phase-in Report, Volume 4 of 15. "Environmental Safety & Health", for the period 10/25/85 through 12/31/85. Prepared for the U.S. DOE by WMCO under Contract No. DE-AC05-860R21620, dated January 17, 1986.

11. Environment, Safety & Health: Information on Three Ohio Defense Facilities. United States General Accounting Office. Publication NO. GAO/RCED-86-51 FS, November 1985.

12. Article in <u>The Communicator</u> titled: "Why wear wrist badges", Vol. 86-10, October 1986.

13. Article in <u>The Communicator</u> titled: "Plant 4 Applauded for Successful Restart", Vol. 87-7 July/August, 1987.

14. Letter, S.L. Hinnefeld to WMCO worker. Assessment of internal dose from exposure to plutonium materials (WMCO:OSH (ODI):88-489), dated December 11, 1988.

15. Letter, [redacted] to [redacted]. 1986 WMCO ALARA goals (WMCO:EH(HP):87-0025), dated February 10, 1987.

## X. AUTHORSHIP AND ACKNOWLEDGEMENTS


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## XI. DISTRIBUTION AND AVAILABILITY OF REPORT

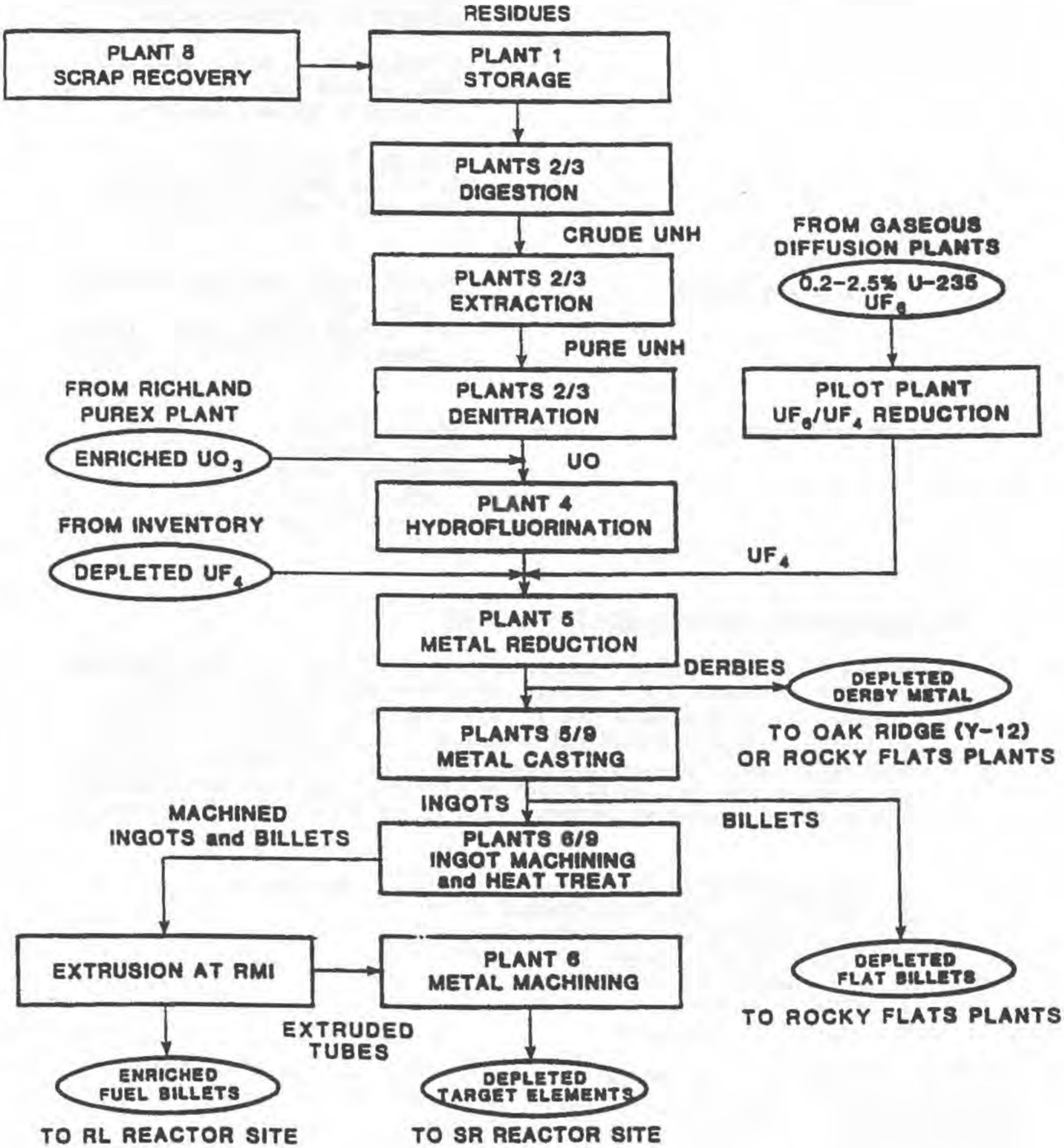
Copies of this report are temporarily available upon request from NIOSH, Hazard Evaluations and Technical Assistance Branch, 4676 Columbia Parkway, Cincinnati, Ohio 45226. After 90 days, the report will be available through the National Technical Information Service (NTIS), 5285 Port Royal, Springfield, Virginia 22161. Information regarding its availability through NTIS can be obtained from NIOSH Publications Office at the Cincinnati address. Copies of this report have been sent to:

1. International Association of Machinists, District 34
2. Westinghouse Materials Company of Ohio
3. U.S. Department of Energy
4. Fernald Atomic Trades Labor Council
5. Congressional Representatives
6. OSHA, Region V
7. Others, as requested

For the purpose of informing affected employees, copies of this report shall be posted by the employer in a prominent place accessible to the employees for a period of 30 calendar days.

Figure 1

# SCHEMATIC DIAGRAM OF THE FMPC PROCESS




Source: "General Overview of FMPC Operations" Manual

Table 1

Summary of Environmental Chemical Exposure Monitoring

Westinghouse Materials Company of Ohio
Fernald, Ohio
HETA 83-144

December 2-3, 1987

| Plant | Plant's Primary Production Activites | Job Classification of Monitored Workers/ Areas Monitored | Air Contaminant(s) Monitored | Source(s) of Contaminant(s) |
|---|---|---|---|---|
| Sampling Plant (Plant 1) | Sampling and assaying of drummed uranium-bearing materials; milling and classifying of feed materials | Sampling line sampler and helper, mill operator, slag drummer | Total (particulate and gaseous) fluorides | Delidding and lidding of drums containing uranium-bearing materials; milling and drumming of magnesium fluoride |
| Metal Dissolver Plant (Plant 2) | Digestion of ore concentrates in nitric acid to form uranyl nitrate (UN); extraction of UN using tributyl phosphate and kerosene; denitration of UN to form uranium oxide | Extraction operator; digestion area | Nitric acid, nitrogen dioxide | Fugitive emissions from uranyl nitrate feed tanks and primary extraction column |
| Green Salt Plant (Plant 4) | Conversion of uranium oxide ($UO_3$) to uranium tetrafluoride ($UF_4$) in reactors, utilizing HF; blending/packaging of $UF_4$; operation of tank farm | Talcum reactor operator, main panel board operator, tank farm operator; ammonia dissociator area | Hydrofluoric acid, ammonia | Packing $UF_4$ (green salt) into drums; tank farm operations |
| Metals Production Plant (Plant 5) | Uranium metal produced from reaction of $UF_4$ and magnesium metal; machining graphite | Jolter, F machine, capping station, breakout hoist station, derby slag cleaning, lidder operators; graphite machinists | Total (particulate and gaseous) fluorides, graphite | Lining of steel pot with MgF slag (jolter); charging mixture of $UF_4$ and Mg metal chips (F machine); capping pot with MgF slag; placing lid on pot; removal of slag from pots using chipping hammers; machining graphite for crucibles |
| Metal Fabrication Plant (Plant 6) | Machining of uranium metal "flats"; metal pickling with nitric acid | Chip pickling tank and scrap pickling tank operators; sump treatment area | Nitric acid, nitrogen dioxide, oil mist | Emissions from nitric acid pickling tanks; machining of uranium metal utilizing water-soluble coolant |
| Special Products Plant (Plant 9) | Machining of uranium metal ingots; derby pickling | Lathe and rapid borer machine operators; Zirnlo | Oil mist, nitric acid, nitrogen dioxide | Machining of uranium metal utilizing a water-soluble coolant or a petroleum-based cutting fluid; emission from nitric acid pickling tanks |
| Pilot Plant (Plant 37) | Production of $UF_4$ green salt from $UF_6$ | Drum packout operator, utility man; ammonia dissociator area | Total (particulate and gaseous) fluorides, hydrogen fluoride, ammonia | Drumming of $UF_4$, fugitive emissions from HF recovery process or ammonia dissociators |

Table 2

NIOSH (N) and Westinghouse (W)
Sampling and Analysis Methodology

Westinghouse Materials Company of Ohio
Fernald, Ohio
HETA 83-144

| Substance | | Collection Device | Flowrate (Lpm) | Sampling Duration Range (hrs) | Analysis | Detection Limit (ug/sample) | Sampling/ Analytical Method 6,7,8 |
|---|---|---|---|---|---|---|---|
| Ammonia | (N) | Draeger long-term indicator tube | 0.020 | 7.0 | Visual | - | - |
| | (W) | $H_2SO_4$-treated silica gel | 0.150 | 7.0 | Ion-specific electrode | 10 | 6701 |
| Fluorides (particulate) | (N) | 37 mm, 0.8 um cellulose ester membrane filter and untreated backup pad | 1.5 | 4.2-6.9 | Ion-specific electrode | 2.0 | 7902 |
| | (W) | 37 mm, 0.8 um cellulose ester membrane filter and untreated backup pad[1] | 2.0 | 4.2-6.9 | Ion-specific electrode | 6.0 | WMCO |
| Fluorides (gaseous) | (N) | 37 mm, sodium carbonate-treated backup pad[1] | 1.5 | 4.2-6.9 | Ion-specific electrode | 2.0 | 7902 |
| | (W) | 37mm, potassium carbonate-treated, 0.8 um mixed cellulose ester filter (2) and untreated backup pad[1] | 2.0 | 4.2-6.9 | Ion-specific electrode | 0.4 | |
| Graphite (total dust) | (N) | Tared 37 mm, 5 um PVC filter | 2.5 | 4.8-6.4 | Gravimetric[2] | 10 | 0500 |
| | (W) | Tared 37 mm, 5 um PVC filter | 2.0 | 4.8-6.4 | Gravimetric[2] | 300 | 0500 |
| Hydrogen flouride | (N) | Sorbent tube containing 600 mg silica gel | 0.20 | 3.3-6.7 | Ion chromatography | 2.0 | 7903 |
| | (W) | Sorbent tube containing 600 mg silica gel | 0.20 | 3.3-6.7 | Ion chromatography | 1.2 | 7903 |
| Nitric acid | (N) | Sorbent tube containing 600 mg silica gel | 0.20 | 3.1-7.1 | Ion chromatography | 0.05 | 7903 |
| | (W) | Sorbent tube containing 600 mg silica gel | 0.20 | 3.1-7.1 | Ion chromatography | 1.2 | 7903 |

continued

Table 2 (continued)

NIOSH (N) and Westinghouse (W)
Sampling and Analysis Methodology

Westinghouse Materials Company of Ohio
Fernald, Ohio
HETA 83-144

| Substance | | Collection Device | Flowrate (Lpm) | Sampling Duration Range (hrs) | Analysis | Detection Limit (ug/sample) | Sampling/ Analytical Method |
|---|---|---|---|---|---|---|---|
| Nitrogen dioxide | (N) | Palmes tube (triethanolamine treated) | passive | 3.1-7.1 | Visible absorption spectrophotometry | 0.01 | 6700 |
| | (W) | Triethanolamine-coated molecular | 0.50 | 3.1-7.1 | Visible absorption spectrophotometry | 0.47 | 5320 |
| Oil mist | (N) | Tared 37 mm, 5 um PVC filter | 1.5 | 5.4-6.2 | Gravimetric[2] | 10 | 0500 |
| | (W) | Tared 37 mm, 3 um PVC filter | 2.0 | 5.4-6.2 | Gravimetric[2] | 10 | OSHA IIMIIS 5010 |

1. The sampling procedure used by NIOSH and Westinghouse for particulate and gaseous fluorides differed slightly. In the NIOSH method, filter media for particulate and gaseous fluorides were each contained in separate cassettes situated in-line on the same sampling train with the particulate fluoride cassette preceding the gaseous fluoride cassette. In the Westinghouse method, all four filters were contained in the same cassette, with the particulate fluoride filter preceding those for gaseous fluorides.

2. Weight gain was assumed to be the contaminant of interest. This is a conservative approach since other particulate present in the work place air would contribute to the total weight gain of the filter.

3. NIOSH analytical methods unless otherwise noted.

TABLE 3

DOE Occupational Radiation
Dose Equivalent Limits According to DOE
Order 5480.1, Chapter XI, Dated 8/13/81

| Exposure Category | LIMIT | |
|---|---|---|
| | REM* Per Year | REM Per Quarter |
| Whole Body Head and Trunk, Gonads, Lens of Eye, Red bone marrow, active blood-forming organs | 5 | 3 |
| Unlimited areas of skin (except hands and forearms). Other organs, tissue and organ system (except bone) | 15 | 5 |
| Bone and Forearms | 30 | 10 |
| Hands and Feet | 75 | 25 |

*REM = roentgen equivalent man: the dosage of ionizing radiation that will cause the same biological effect as one roentgen of x-ray or gamma-ray.

Table 4

Evaluation Criteria and Health Effects Summary

Westinghouse Materials Company of Ohio
Fernald, Ohio
HETA 83-144

December 2-3, 1987

| Substance | Environmental Criteria[1] (mg/m$^3$) NIOSH REL | OSHA PEL | ACGIH TLV | Primary Health Effects References | References |
|---|---|---|---|---|---|
| Ammonia | 35(c) | 35 | 18 | Ammonia is a severe irritant of the eyes, respiratory tract and skin. Acute exposure to high concentrations of ammonia gas may produce severe burns of the cornea and skin. Repeated exposure may cause chronic irritation of the conjunctiva and upper respiratory tract. | 10,11,12 |
| Fluorides (total) | 2.5 | 2.5 | 2.5 | Flouride causes irritation of the eyes and respiratory tract. Repeated or prolonged exposure of the skin to fluoride containing dusts and fumes may cause dermatitis. | 10,11,13 |
| Graphite (synthetic) | - | 15 | 10 | Considered a nuisance particulate. Excessive concentrations of nuisance particulate may cause unpleasant deposits in the eyes, ears, and nasal passages, and may seriously reduce workroom visibility. | 10,11,14 |
| Hydrogen flouride | 2.5 | 2.5 | 2.5(c) | Inhalation of hydrogen flouride (HF) produces irritation of the eyes, nose, and respiratory tract. HF solutions in contact with skin may cause necrosis of soft tissues and decalcification of bone. | 10,11,15 |
| Nitric acid | 5 | 5 | 5 | Nitric acid is an irritant of the eyes, mucuous membranes, and skin. Dental erosion may result upon exposure to vapor and mist. | 10,11,16 |
| Nitrogen dioxide | 1.8(c) | 9(c) | 6 | Nitrogen dioxide produces eye and respiratory tract irritation. | 10,11,17 |
| Oil mist (mineral) | - | 5 | 5 | Pulmonary effects are rare. Skin contact with liquid oil can cause dermatitis. | 10,11,14 |

1. Values are in milligrams per cubic meter (mg/m$^3$) and represent time-weighted average (TWA) exposure limits for up to a 10 hour workday unless otherwise specified.

2. Nuisance dust classification is based on presence of less that 1% (by weight) quartz in bulk dust sample. If greater than 1%, personal samples must be analyzed for crystalline silica compared to its evaluation criteria.

(c) Ceiling limit; exposure shall not exceed this concentration.

Table 5

Whole Body (Penetrating) and Skin (Non-Penetrating)
Exposure Summary for All WMCO Personnel During 1984-1987

Westinghouse Materials Company of Ohio
Fernald, Ohio
HETA 83-144

December 2-3, 1987

| Year | Exposure Type | Total Badges | Badges Having No Exposure | Less Than 1 Rem | 1 to 1.99 Rems | 2 to 4.99 Rems | 5 to 9.99 Rems | 10 to 11.99 Rems |
|---|---|---|---|---|---|---|---|---|
| 1984 | WB | 1146 | 441 | 705 | 0 | 0 | 0 | 0 |
| | S | 1146 | 352 | 380 | 135 | 187 | 83 | 9 |
| 1985 | WB | 1465 | 540 | 925 | 0 | 0 | 0 | 0 |
| | S | 1465 | 482 | 559 | 158 | 197 | 68 | 1 |
| 1986 | WB | 1823 | 666 | 1157 | 0 | 0 | 0 | 0 |
| | S | 1823 | 630 | 730 | 172 | 196 | 91 | 4 |
| 1987 | WB | 1785 | 627 | 1155 | 0 | 0 | 0 | 0 |
| | S | 1785 | 601 | 791 | 150 | 166 | 74 | 2 |

WB - Whole Body
S - Skin

Table 6

Job Dose Estimates*
Plant 5
Reduction Area

| Job | Estimated Averages (mrem/day) (6hr/ day) | | (mrem/week) (30hr/week) | |
|---|---|---|---|---|
| | Skin | WB | Skin | WB |
| Top F | 12 | 3 | 60 | 15 |
| Bottom F | 22 | 5 | 110 | 25 |
| Cap and Lid | 8 | 1 | 40 | 5 |
| Jolter | 9 | 1.5 | 45 | 7.5 |
| Rockwell | 10 | 1.5 | 50 | 7.5 |
| Breakout (no pit) | 32 | 3 | 160 | 15 |
| Building 55 | 8 | 1 | 40 | 5 |
| Residue | 10 | 2 | 50 | 10 |
| DP | 12 | 2 | 60 | 10 |
| Pit Breakout | | | | |
| | | Remelt Area | | |
| Top Furnace | 25 | 8 | 125 | 40 |
| Bottom Furnace | 34 | 6 | 170 | 30 |
| Burnout | 82 | 9 | 410 | 45 |
| Residue (graphite break burnout oxide) | 69 | 7.5 | 345 | 37.5 |
| Saw | 52 | 6 | 260 | 30 |
| Charging (no ARF or specials) | 55 | 7 | 275 | 35 |
| DP | 15 | 3.5 | 75 | 17.5 |
| Stamp Flats | 30 | 4 | 150 | 20 |
| Hoist Operator | 45 | 7 | 225 | 35 |
| Separations Operation | 62 | 8 | 310 | 40 |
| Reconditioning | 67 | 7 | 335 | 35 |

*Source of information - WMCO Environmental Safety and Health Staff

Table 7

Comparison of NIOSH and WMCO Plantwide
Side-by-Side Radiological Air Sample Measurements

Feed Material Production Center
Fernald, Ohio
HETA 83-144

December 2-3, 1987

| Plant | NIOSH Results | | WMCO Results | |
|---|---|---|---|---|
| | Alpha | Beta | Alpha | Beta |
| Pilot | $1.14x10^{-13}$ | $1.82x10^{-12}$ | $4.50x10^{-13}$ | $4.67x10^{12}$ |
| 1 | $1.67x10^{-13}$ | $3.90x10^{-13}$ | $7.65x10^{-13}$ | $2,68x10^{-12}$ |
| 2/3 | $1.73x10^{-13}$ | $5.80x10^{-13}$ | $8.69x10^{-13}$ | $3.57x10^{-12}$ |
| 4 | $1.40x10^{-12}$ | $3.50x10^{-12}$ | $1.21x10^{-12}$ | $3.38x10^{-12}$ |
| 5a | $4.20x10^{-12}$ | $4.30x10^{-11}$ | $4.76x10^{-12}$ | $5.30x10^{-11}$ |
| 5b | $8.70x10^{-12}$ | $2.50x10^{-10}$ | $5.60x10^{-12}$ | $2.80x10^{-10}$ |
| 5c | $3.90x10^{-10}$ | $7.10x10^{-11}$ | L O S T | S A M P L E |
| 5d | $4.00x10^{-12}$ | $4.50x10^{-11}$ | $2.92x10^{-12}$ | $4.60x10^{-11}$ |
| 5e | $1.10x10^{-11}$ | $2.10x10^{-12}$ | $4.80x10^{-12}$ | $1.60x10^{-10}$ |
| 6 | $8.30x10^{-13}$ | $3.20x10^{-12}$ | $3.40x10^{-13}$ | $1.70x10^{-12}$ |
| 9a | $5.50x10^{-12}$ | $2.10x10^{-11}$ | $6.00x10^{-12}$ | $2.30x10^{-11}$ |
| 9b | $1.20x10^{-12}$ | $5.60x10^{-12}$ | $1.70x10^{-12}$ | $1.10x10^{-11}$ |

Samples reported in units of microcuries per cubic centimeter (uCi/cc).

Table 8

FMPC Radiation Air Sample Synopsis for Calendar Year 1987 (through 7/20/87)

Feed Materials Production Center
Fernald, Ohio
HETA 83-144

December 2-3, 1987

| Plant | Number Samples | Highest Alpha Level | Highest Beta Level |
|---|---|---|---|
| Pilot | 568 | $1.79x10^{-11}$ | $7.30x10^{-10}$ |
| 1 | 164 | $1.80x10^{-11}$ | $4.98x10^{-11}$ |
| 2/3 | 285 | $8.34x10^{-11}$ | $4.03x10^{-10}$ |
| 4 | 2505 | $6.12x10^{-11}$ | $1.30x10^{-9}$ |
| 5 | 2121 | $2.35x10^{-10}$* | $2.98x10^{-9}$ |
| 6 | 845 | $4.69x10^{-11}$ | $1.13x10^{-10}$ |
| 8 | 130 | $7.92x10^{-11}$ | $4.35x10^{-10}$ |
| 9 | 1381 | $3.72x10^{-10}$* | $1.48x10^{-9}$ |
| Bldg 71 | 55 | $6.94x10^{-10}$* | $1.44x10^{-9}$ |
| Composite | 8054 | $6.94x10^{-10}$ | $2.98x10^{-9}$ |

Samples reported in units of microcuries per cubic centimeter (uCi/cc).

* Level above DOE alpha limit of $1x10^{-10}$ uCi/cc

Table 9

Total (particulate and gaseous) Fluoride Concentrations - Sampling Plant (Plant 1)

Westinghouse Materials Company of Ohio
Fernald, Ohio
HETA 83-144

December 2-3, 1987

| Sample Description | Sampling Time (min) | Sample Volume (liters) | Fluorides (mg/m³) Particulate | Gaseous** | Total |
|---|---|---|---|---|---|
| Mill operator, PBZ | 324 | 486<br>[648] | 0.006<br>[0.04] | ND<br>NS | 0.006 |
| Slag drummer, PBZ | 309 | 463<br>[618] | 0.02<br>[0.08] | ND<br>NS | 0.02 |
| Sampling line Sampler, PBZ* | 328 | 492<br>[656] | 0.01<br>[0.05] | (0.006)<br>NS | 0.01 |
| Sampling line helper, PBZ* | 326 | 489<br>[652] | 0.005<br>[<0.03] | ND<br>NS | 0.005 |
| Evaluation Criteria: | | | 2.5 | 2.5 | 2.5 |

ND = not detected, less than 0.004 mg/m$^3$. Values between the limit of detection and the limit of quantitation are considered semi-quantitative data and are parenthesized.

NS = not sampled; WMCO did not consider the gaseous form of fluorides to be generated in these operations.

PBZ = personal breathing-zone sample

[ ] corresponding values reported by WMCO

* wore half mask respirator with HEPA filters when sampling dusty waste material.

** Values may be higher than reported (see Appendix B).

Table 10

Nitric Acid and Nitrogen Dioxide Concentrations - Metal Dissolver Plant (Plant 2)

Westinghouse Materials Company of Ohio
Fernald, Ohio
HETA 83-144

December 2-3, 1987

| Sample Description | Sampling Time (min) | Sample Volume (liters) | | Environmental Concentration (mg/m³) | |
|---|---|---|---|---|---|
| | | Nitric Acid | Nitrogen Dioxide | Nitric Acid | Nitrogen Dioxide |
| Extraction operator, PBZ | 349 | 64.9<br>[64.9] | -[A]<br>[175] | 0.06<br>[0.18] | ND[B]<br>[0.05] |
| Extraction operator, PBZ | 289 | 70.1<br>[70.1] | -<br>[145] | 0.07<br>[<0.07] | 0.17<br>[<0.02] |
| Uranyl nitrate feed tanks, digestion area, GA | 425 | 83.9<br>[83.9] | -<br>[212] | 0.34<br>[0.26] | 0.60<br>[0.17] |
| Evaluation Criteria: | | | | 5.0 | 1.8 |

A. There is no air sample volume associated with the Palmes tube sampler

B. Worker reported that Palmes tube dropped into sink and had water enter it. This may explain why $NO_2$ was not detected in this sample. His exposure was probably similar to that of the other extraction operator.

PBZ = Personal breathing-zone sample; GA = general area sample

[ ] - corresponding values reported by WMCO

Table 11

Hydrogen Fluoride and Ammonia Concentrations - Green Salt Plant (Plant 4)

Westinghouse Materials Company of Ohio
Fernald, Ohio
HETA 83-144

December 2-3, 1987

| Sample Description | Sampling Time (min) | Sample Volume (liters) | | Environmental Concentration ($mg/m^3$) | |
|---|---|---|---|---|---|
| | | Hydrogen Fluoride | Ammonia | Hydrogen Fluoride | Ammonia |
| Tank farm operator, PBZ | 310 | 62<br>[62] | -<br>[46.5] | ND<br>[0.02] | **<br>[<0.20] |
| Talcum reactor operator, PBZ | 403 | 78<br>[60] | -<br>- | ND<br>[0.06] | NS |
| $UF_4$ drum station operator<br>Main panel board operator; PBZ* | 200 | 37<br>[40] | -<br>- | ND<br>[0.05] | NS |
| Ammonia dissociators, GA | 419 | -<br>- | 8.4<br>[63] | NS | 2.2<br>[0.35] |
| Evaluation Criteria: | | | | 2.5 | 18 |

ND = not detected; the environmental limit of detection for HF was calculated to be no greater than 0.03 $mg/m^3$, based on the lowest sample air volume.

NS = not sampled; there was no potential for exposure to ammonia in this operation.

PBZ = personal breathing zone sample; GA = general area sample

[ ] - corresponding values reported by WMCO

* $UF_4$ drum station operator wore half mask respirator with HEPA filters when packing out green salt, an operation which lasted about 1.5 hours on the day of our survey. This same worker operated the main panel board the remainder of the shift.

** Sample not collected.

Table 12

Total (particulate and gaseous) Fluoride and Graphite Concentrations - Metals Production Plant (Plant 5)

Westinghouse Materials Company of Ohio
Fernald, Ohio
HETA 83-144

December 2-3, 1987

| Sample Description | Sampling Time (min) | Sample Volume (liters) | Environmental Concentration (mg/m3) Fluoride Particulate | Gaseous* | Total | Graphite |
|---|---|---|---|---|---|---|
| East jolter operator, PBZ | 412 | 618 [824] | 0.13 [0.36] | ND [0.01] | 0.13 [0.37] | NS |
| East jolter operator, PBZ | 374 | 561 [748] | 0.20 [0.16] | ND [0.02] | 0.10 [0.18] | NS |
| Top F machine operator, PBZ | 254 | 381 [508] | 0.02 [0.03] | ND [0.10] | 0.02 [0.13] | NS |
| Bottom F machine operator, PBZ | 349 | 523 [698] | 0.18 [0.21] | ND [0.03] | 0.18 [0.24] | NS |
| East capping station operator, PBZ | 369 | 553 [738] | 0.05 [0.10] | ND [0.05] | 0.05 [0.15] | NS |
| Lidder operator, PBZ | 361 | 541 [722] | 0.20 [0.17] | ND [0.06] | 0.20 [0.23] | NS |
| Breakout operator, PBZ | 354 | 531 [708] | 0.07 [0.15] | ND [0.02] | 0.07 [0.17] | NS |
| Derby slag cleaning operator, PBZ | 354 | 531 [578] | 0.09 [0.10] | ND [0.02] | 0.09 [0.12] | NS |
| Graphite machinist, PBZ | 289 | 921 [578] | NS | NS | - | 0.35 [1.2] |
| Graphite machinist, PBZ | 323 | 807 [646] | NS | NS | - | 0.58 [1.7] |
| Graphite machining room, GA | 382 | 955 [764] | NS | NS | - | 0.18 [0.59] |
| Evaluation Criteria: | | | 2.5 | 2.5 | 2.5 | 10 |

NS - not sampled; there was no potential for exposure to this substance in this operation
ND - not detected, the environmental limit of detection for HF was calculated to range from 0.003 and 0.005 mg/m$^3$.
These values may be higher than reported (see Appendix).
PBZ - personal breathing zone sample, GA - general area sample
[ ] - corresponding values reported by WMCO.

Table 13

Nitric Acid, Nitrogen Dioxide and Oil Mist Concentrations - Metals Fabrication Plant (Plant 6)

Westinghouse Materials Company of Ohio
Fernald, Ohio
HETA 83-144

December 2-3, 1987

| Sample Description | Sampling Time (min) | Sample Volume (liters) | | | Environmental Concentration (mg/m$^3$) | | |
|---|---|---|---|---|---|---|---|
| | | $HNO_3$ | $NO_2$ | Oil Mist | $HNO_3$ | $NO_2$ | Oil Mist |
| Chip pickling tank operator, PBZ* | 185 | 36<br>[36] | -<br>[92] | -<br>- | 1.01<br>[0.77] | 1.88<br>[0.56] | NS |
| Scrap pickling tank operator, PBZ | 384 | 20<br>[20] | -<br>[192] | -<br>- | 1.00<br>[0.26] | 0.11<br>[<0.02] | NS |
| Nitric acid sump treatment work station, GA | 366 | 71<br>[71] | -<br>[183] | -<br>- | 0.04<br>[0.02] | 0.37<br>[<0.02] | NS |
| #6 Cincinnati mill operator, PBZ | 369 | -<br>- | -<br>- | 553<br>[738] | NS | NS | 0.07<br>[0.1] |
| K&T North vertical mill operator, PBZ | 371 | -<br>- | -<br>- | 556<br>[742] | NS | NS | 0.07<br>[0.07] |
| K&T South vertical mill operator, PBZ | 364 | -<br>- | -<br>- | 546<br>[728] | NS | NS | 0.09<br>[0.07] |
| Cincinnati Versi horizontal mill operator, PBZ | 371 | -<br>- | -<br>- | 556<br>[742] | NS | NS | 0.09<br>[0.01] |
| Evaluation Criteria: | | | | | 5 | 1.8 | 5 |

NS - not sampled; there was no potential for exposure to this substance in this operation
PBZ - personal breathing zone sample; GA - general area sample.
A - There is no air sample volume associated with the Palmes tube sampler.
[ ] - corresponding values reported by WMCO.

Table 14

Oil Mist, Nitric Acid and Nitrogen Dioxide Concentrations - Special Products Plant (Plant 9)

Westinghouse Materials Company of Ohio
Fernald, Ohio
HETA 83-144

December 2-3, 1987

| Sample Description | Sampling Time (min) | Sample Volume (liters) | | | Environmental Concentration ($mg/m^3$) | | |
|---|---|---|---|---|---|---|---|
| | | Oil mist | Nitric acid | Nitrogen dioxide | Oil mist | Nitric acid | Nitrogen dioxide |
| LeBlond rapid borer operator, PBZ | 325 | 487 [650] | - - | - - | 0.10 [0.2] | NS | NS |
| 5L lathe Operator, PBZ | 346 | 519 [692] | - - | - - | 0.17 [0.2] | NS | NS |
| 5L lathe operator, PBZ | 343 | 514 [686] | - - | - - | 0.45 [0.4] | NS | NS |
| Gisholt 4L lathe operator, PBZ | 338 | 508 [676] | - - | - - | 0.37 [0.4] | NS | NS |
| Zirnlo operator, PBZ | 195 | - - | 39 [39] | A [97] | NS | 0.05 [<0.15] | 0.37 [<0.05] |
| Evaluation Criteria: | | | | | 5 | 5 | 1.8 |

NS = not sampled; there was no potential for exposure to this substance in this operation.
PBZ - personal breathing zone sample.
[ ] - Corresponding values reported by WMCO.
A - There is no air sample volume associated with the Palmes tube sampler.

Table 15

Total (particulate and gaseous) Fluorides, Hydrogen Fluoride, and Ammonia Concentrations - Pilot Plant

Westinghouse Materials Company of Ohio
Fernald, Ohio
HETA 83-144

December 2-3, 1988

| Sample Description | Sampling Time (min) | Sample Volume (liters) | | | Environmental Concentration ($mg/m^3$) | | | | |
|---|---|---|---|---|---|---|---|---|---|
| | | | | | Fluorides | | | | |
| | | Fluorides | HF | $NH_3$ | Part. | Gas. | Total | HF | $NH_3$ |
| Drum packout operator, PBZ | 390 | 585 [780] | 75 [75] | - | 0.005 [0.05] | (0.003) NA | 0.008 | ND [0.05] | NS |
| Utility man, PBZ | 363 | 543 [726] | 60 [60] | - | (0.001) [0.03] | ND NA | 0.001 | ND [0.01] | NS |
| Ammonia dissociators, GA | 419 | - | - | 8.4 [63] | NS | NS | - | NS | 0.6 [<0.16] |
| Evaluation Criteria: | | | | | | | 2.5 | 2.5 | 18 |

(  ) - Values between the limit of detection and the limit of quantitation are considered semiquantitative data.
ND - Not detected; based on the lowest sample air volume the environmental limit of detection was calculated to be no greater than 0.005 $mg/m^3$.
NS - Not sampled; there was no potential for exposure to this substance in this operation.
PBZ = Personal breathing zone sample, GA - general area sample.
[  ] - corresponding values reported by WMCO.

APPENDIX A

DEPARTMENT OF HEALTH AND HUMAN SERVICES
CENTERS FOR DISEASE CONTROL
NATIONAL INSTITUTE FOR OCCUPATIONAL SAFETY AND HEALTH
CINCINNATI, OHIO 45226

Report of Medical Study
HETA 83-144

FEED MATERIALS PRODUCTION CENTER
FERNALD, OHIO

JULY 1987

## I. SUMMARY


In September 1985, personnel from the National Institute for Occupational Safety and Health (NIOSH) conducted a cross-sectional medical study of workers at the Feed Materials Production Center (FMPC), a uranium processing facility owned by the United States Department of Energy and operated, at the time of the study, by NLO, Inc. The study included a medical and occupational history questionnaire, urine and blood tests for several indicators of renal function and damage, a chest x-ray, pulmonary function tests, and determination of uranium concentration in a post-shift urine sample. Company personnel records and urine uranium monitoring data were used to construct work and exposure histories.

One hundred forty-six (70%) of 208 eligible long-term employees participated. They had worked at the FMPC from 10 to 34 years, with a median of 32. Indicators of uranium exposure included self-reported uranium exposure "incidents", having been told of a high radiation badge reading, having been told of being overexposed to uranium, length of time at FMPC, current job exposure category, and an index of cumulative uranium exposure derived from the job history and historical urine uranium data. [The 118 urine uranium concentrations measured during the NIOSH survey were all less than 15 micrograms per liter (ug/l); 109 were less than 5 ug/l.]

The study demomstrated some associations between respiratory effects and indicators of uranium exposure. The ratio of the one-second forced expiratory volume to the forced vital capacity ($FEV_1$/FVC) was associated with the uranium exposure index, even after accounting for cigarette smoking. Shortness of breath was not associated with the uranium exposure index, but was significantly associated with self-reported uranium exposure incidents. Neither chronic cough nor chronic bronchitis was associated with any of the indicators of uranium exposure. Pleural thickening on x-ray was not associated with indicators of uranium exposure or with self-reported history of asbestos exposure. None of the 130 x-rays had increased interstitial markings suggestive of pneumoconiosis.

Renal effects were evaluated treating blood and urine test results as both dichotomous variables (abnormal/normal) and continuous variables. There were no associations between test results and any indicator of uranium exposure, using both raw and creatinine-standardized test results. This apparent lack of any exposure-related renal effects might have been due to limitations of the study, including participation bias, recall bias, an imperfect uranium exposure index, and inadequately sensitive measures of uranium nephrotoxicity.

Future activities will include (a) an environmental evaluation of various exposures at the FMPC, and (b) additional analyses of the company's urine uranium monitoring data in conjunction with the NIOSH renal test results to determine if there is any association between renal effects and the amount of individually measured past uranium exposure.

## II. INTRODUCTION

In February 1983, the National Institute for Occupational Safety and Health (NIOSH) received a request from District 34, International Association of Machinists, to evaluate potentially hazardous exposures at the Feed Materials Production Center (FMPC), Fernald, Ohio. The plant is owned by the U.S. Department of Energy (DOE), was operated at the time of the request by NLO, Inc. (NLO), and since January 1, 1986, has been operated by Westinghouse Materials Company of Ohio (WMCO). The requester and other employee representatives expressed concern about a number of potential health problems and exposures.

NIOSH investigators conducted a walk-through inspection of the facility on October 12, 1983. Among the numerous potential exposures noted at the time were uranium (both metallic and various soluble and insoluble compounds, including uranium oxides and fluorides), hydrogen fluoride, nitric acid, tributylphosphate, and other chemicals. Although the FMPC had authorization to handle uranium up to 19.99% enriched, relatively little uranium of more than 10% enrichment was used;[1] in most work areas at the FMPC, the uranium was low-enriched (<2%) or depleted. [Natural uranium contains 99.3% $U^{238}$ and 0.7% $U^{235}$, which is a greater radiologic health hazard than $U^{238}$. Enriched uranium contains more than 0.7% $U^{235}$, the percent enrichment denoting the amount. Depleted uranium contains less than 0.7% $U^{235}$.] Thorium had been processed in the past, as had material containing plutonium. Also, asbestos was used in the construction of some buildings.

After discussions with the requester, other union representatives and consultants, and representativies of DOE and NLO, the NIOSH investigators decided to concentrate the medical component of the hazard evaluation on screening for evidence of lung and kidney toxicity. This decision was based on (a) case reports by the requester and union medical consultants of several instances of lung disease among past and present workers, (b) the known toxic effects of soluble forms of uranium on the kidney, (c) the respiratory effects of several substances used at the plant, and (d) the relatively low enrichment of uranium at the plant, making chemical, rather than radiologic, toxicity the predominant concern.

The investigation encountered considerable delay as a result of administrative procedures required by DOE before allowing NIOSH access to necessary employee medical and personnel records. NIOSH personnel finally conducted a medical field survey September 16-27, 1985. Individual employees were notified of their pulmonary function test and chest x-ray results June 25, 1986, and of their blood and urine test results July 23, 1986. This report presents the results of the medical survey.

## III. METHODS

The medical study was designed to detect evidence of pulmonary (lung) and renal (kidney) damage or dysfunction attributable to uranium exposure. Accordingly, employees meeting the following criteria were eligible to participate: (a) current hourly employees (production and maintenance workers and security guards) who had worked at the plant continuously for at least 10 years; (b) current salaried employees who had previously been hourly employees and who had been at the plant at least 10 years; (c) salaried employees who had worked at the plant continuously for at least 10 years and whose current job category, according to consensus of management and union representatives, involved potential exposure to uranium; and (d) former hourly employees who had retired within the preceding two years after having worked continuously at the plant for at least 10 years. (Considering both total dose of uranium and disease latency, any effects of chronic exposure to uranium would most likely be found among those employees with the longest exposure. Ten years represented a period of sufficient latency that still provided an adequately large population for study.)

Eligible current employees were identified through employee rosters and scheduled by the company for a meeting with NIOSH personnel, who explained the study and requested worker participation. The NIOSH investigators also sent to all eligible retirees who could be identified from company records a letter describing the study and inviting their participation. Finally, the NIOSH investigators contacted current workers on sickness or disability leave to determine the cause of their absence.

The medical study included a medical and occupational history questionnaire, a chest x-ray, standard screening spirometry, blood and urine analyses for several parameters of kidney function, and determination of urine uranium concentration.

The questionnaire was self-administered in small groups under the direction of NIOSH personnel. It elicited basic demographic information, presence of respiratory symptoms, history of urinary tract problems, history of medical conditions known to predispose to renal dysfunction, use of medications that might affect the test results, current job information, past and present workplace exposures (at NLO and elsewhere), and use of cigarettes and alcoholic beverages. The respiratory questions were adapted from the American Thoracic Society questionnaire.[2] For the epidemiologic purposes of this study, we defined chronic bronchitis as cough and phlegm on most days, for at least three consecutive months a year, for at least two years.[3] By analogy, we defined chronic cough as cough on most days, at least three consecutive months a year, for at least two years. We categorized the degree of breathlessness (dyspnea) according to the responses to the five pertinent questions on the questionnaire.

Grade 1 -- troubled by shortness of breath when hurrying on the level or walking up a slight hill.

Grade 2 -- having to walk slower (on the level) than people of the same age because of shortness of breath.

Grade 3 -- having to stop for breath when walking at one's own pace on the level.

Grade 4 -- having to stop for breath after walking about 100 yards (or after a few minutes) on the level.

Grade 5 -- too breathless to leave the house or breathlessness on dressing or undressing.

Chest x-rays were interpreted according to the ILO 1980 International Classification of Radiographs of Pneumoconioses.[4] Each x-ray was read independently by two radiologists certified in the use of the ILO system ("B readers"). In cases of disagreement, the x-ray was read independently by a third B reader, and the majority opinion (or median value) of a disputed finding was used for analysis (and for reporting results to the participants). None of the radiologists knew the exposure status of the persons whose x-rays they were interpreting.

One-second forced expiratory volume ($FEV_1$) and forced vital capacity (FVC) were measured with an Ohio Medical Model 822 dry rolling seal spirometer attached to a Spirotech 200B dedicated computer. Equipment and test procedures conformed to the American Thoracic Society's criteria for screening spirometry.[5] Predicted values for $FEV_1$ and FVC were calculated using the equations of Knudson;[6] these values were multiplied by 0.85 to obtain the predicted values for Blacks.[7] We used FVC $<80\%$ of predicted with $FEV_1/FVC \geq 70\%$ as the criterion for a pure restrictive pulmonary function pattern, and $FEV_1/FVC < 70\%$ with FVC $\geq 80\%$ of predicted as the criterion for a pure obstructive pattern. We defined FVC $<80\%$ of predicted with $FEV_1/FVC < 70\%$ as a combined obstructive/restrictive pattern.

Venous blood and urine were analyzed for several indicators of renal function and damage, both glomerular and tubular. Specific tests, analytical procedures, and reference ranges are listed in Table 1. We attempted to obtain the first morning urine for all analyses except uranium, which was measured in a post-shift urine specimen obtained on the "clean" side of the employee locker room following the employee's shower. When a first morning urine specimen could not be obtained, we accepted whatever specimen was available.

We abstracted work histories from company personnel records. Each job title was categorized according to potential for uranium exposure and combined into high-, medium-, low-, or no-exposure groups, based on the consensus of company and union representatives and our observations (Appendix A). We extracted information on all previous urine uranium measurements for study participants, which was available from a computerized record of the company's urine uranium monitoring program. We used this historical urine uranium data to validate the exposure categories and to estimate quantitatively the differences between them, that is, to "weight" the categories. For each participant, we then constructed an index estimating cumulative uranium exposure by multiplying the time (in months) spent in each job by the derived category weight for the appropriate job category and summing over all jobs. (Individual urine uranium results were not used to calculate the index.) In essence, this exposure index represents the length of time an employee worked at the FMPC, weighted according to the potential for uranium exposure in the jobs he or she has held there. Finally, we obtained the uranium lung burden data (whole-body radiation counts) for participants who had undergone this examination in the most recent round of testing, which had, coincidentally, occurred during the few weeks preceding our field survey. Radiation measurements were made in a DOE mobile unit; equipment, procedures, minimum detection level, and calculation of maximum permissible lung burden (MPLB) are described in a previous NIOSH report.[1]

Statistical analysis was performed on an IBM Mainframe computer using the Statistical Analysis System (SAS), version 5.08 (SAS Institute, Inc., Carey, NC, 1985).

## VI. RESULTS

### A. Participants

The current employees eligible for the study included 147 wage and 61 salaried workers. One hundred-forty six (70%) of these 208 persons participated, although not all completed all parts of the survey. Unless otherwise noted, the terms "participant" and "study participants" will hereafter refer to these 146. Of the 28 eligible retirees, only 8 (29%) took part in the study. Because of the likely selection bias, these, as well as four other (self-referred) current or former employees who did not meet the eligibility criteria, were excluded from the data analysis. None of the non-participating current employees were on disability or extended sick leave because of lung or kidney problems.

The 146 participants included 142 men and 4 women. There were 138 Whites, 6 Blacks, 1 Native American, and 1 person of unspecified race. They ranged in age from 31 to 68 years, with a median of 58 and mean of 56. One hundred-three (71%) had reached the twelfth grade, and 27 (18%) had had formal education beyond high school. Forty-eight (33%) of the 144 persons answering the question were non-smokers, 65 (45%) were former smokers, and 31 (22%) were current smokers. (The percentages referring to smoking status are based on the 144 participants who answered the question. Hereafter, unless there are more than seven (5%) non-respondents, percentages will be based on a denominator of 146.)

B. Exposures

The participants had worked at the FMPC from 10 to 34 years, with a median of 32 and a mean of 29. Seventy-eight (53%) reported at least 1 uranium exposure "incident," 49 (34%) reported 10 or more, and 38 (26%) reported 20 or more. Although only 22 (15%) reported having ever been told by NLO management or health and safety personnel, or by an outside physician, that they had been overexposed to uranium or radiation, 9 said that they had been told by NLO at least once that their urine uranium level was above the company's action level [40 micrograms per liter (ug/l)], and 29 said that they had been told at least once by NLO that their radiation badge showed excessive radiation exposure. Eight persons (5%) reported having ever been reassigned to a different job because of a high urine uranium level, and 9 (6%) reported a job reassignment for a high radiation badge reading.

Ninety-three (64%) of the participants reported "regular or frequent" exposure to uranium at the FMPC, and another 41 (28%) reported "occasional" exposure (Table 2). A majority also reported at least occasional exposure to thorium, nitric acid, hydrogen fluoride, ammonia, and machining fluids. Seventeen (12%) persons reported regular or frequent exposure to asbestos at the FMPC, and another 38 (26%) reported occasional exposure. None of these questions distinguished between past and present exposures. Four persons reported previous occupational exposure to uranium or other radioactive materials (plutonium, thorium, and polonium) somewhere other than at the FMPC.

Forty-eight (33%) of the participants had had a whole body radiation count in the round of testing preceeding the NIOSH survey. Percent MPLB ranged from 0 to 54 percent, with a median of 11% and a mean of 14%. Percent MPLB was not associated with self-reported uranium exposure incidents (Table 3). For both self-reported history of a high radiation badge reading and being told of overexposure to uranium or radiation, those with such a history had a numerically higher mean percent MPLB than those without, but the differences were not statistically significant. [Because of the low sensitivity of the DOE mobile counter, and the deficiencies (at least prior to the time of our field survey) in the company's method of reporting percent MPLB,[1] the numerical accuracy of most of the percent MPLB values reported above is questionable. Any differences between them are thus also questionable, and any association, or lack of association, between percent MPLB and either other indicators of exposure or indicators of effect may be spurious.]

The mean urine uranium levels associated with the no-, low-, medium-, and high-exposure job categories were 6.2, 6.7, 11.0, and 17.8 ug/l, respectively. These were calculated using all routine and "incident" urine uranium determinations (but excluding follow-up tests) for every study participant recorded on the company's data file. Each of these 12,215 results was allocated to the job the worker had held at the time the respective urine specimen was obtained. Based on the above mean urine uranium concentrations, the no-, low-, medium-, and high-exposure categories were assigned weights (ratio of category mean to no-exposure category mean) of 1, 1.08, 1.77, and 2.87, respectively.

The urine uranium concentrations measured in the 118 study participants ranged up to 13 ug/l; 109 (92%) were less than 5 ug/l, the limit of detection for the analytical method used.

C. Pulmonary effects

Forty-five (31%) participants reported having been on medical disability at least once. Five of them had had one or more lung problems (asthma, bronchitis, pneumonia, chemical pneumonitis due to hydrogen fluoride, benign tumor, and an unspecified lung problem), and two had had unspecified kidney problems.

Fourteen (10%) persons met the criteria for chronic cough; 11 (8%) met the criteria for chronic bronchitis. Neither condition was associated with uranium exposure index (Table 4). Chronic bronchitis, but not chronic cough, was associated with a history of one or more uranium exposure "incidents," but the association with multiple incidents ($\geq$20 versus <20) was weaker (Table 5). Neither chronic cough nor chronic bronchitis was associated with a self-reported high radiation badge reading or with having been told of overexposure to uranium or radiation (Table 5), and neither condition was associated with higher percent MPLB (Table 7). [The lack of accuracy of the percent MPLB values was discussed above (Section IV B).]

Forty-seven (32%) participants reported shortness of breath; 18 (13%) had grade 2 or worse. Of the 10 (7%) with symptoms more severe than grade 2, one had grade 3 and nine had grade 4. Shortness of breath was not associated with the uranium exposure index (Table 4), but was associated with self-reported uranium exposure incidents. Both for those with $\geq 1$ and $\geq 20$ incidents, the relative risk of being symptomatic tended to increase with increasing degree of shortness of breath, and for those with $\geq 20$ incidents the 95% confidence intervals excluded 1 for all grades (Table 5). Similar trends were seen with self-reported high radiation badge readings and with having been told of uranium or radiation overexposure, but the relative risks were smaller and the 95% confidence intervals included 1 (Table 6). Shortness of breath was not associated with higher percent MPLB (Table 7).

One hundred-thirty (89%) of the participants had pulmonary function tests; 112 (86%) of the tests met the validity criteria for epidemiologic analysis.[4] Fourteen (13%) of the valid tests demonstrated a restrictive pattern, and 23 (21%) had an obstructive pattern. (These totals included 5 with a mixed restrictive/obstructive pattern.)

Participants with an obstructive pulmonary function pattern had a significantly higher uranium exposure index than those without an obstructive pattern (Table 4). A similar tendency was also seen for restrictive PFT pattern, but the difference was not statistically significant. Using multiple regression analysis, $FEV_1/FVC$ was associated with both uranium exposure index ($B = -0.0081$, $p = 0.014$) and current smoking status (0 = no, 1 = yes) ($B = -9.18$, $p = 0.0001$), but not with age (years) ($B = -0.095$, $p = 0.53$), duration of employment at the FMPC (months) ($B = -0.0071$, $p = 0.60$), or cumulative smoking (pack-years) ($B = -0.017$, $p = 0.67$). Percent predicted $FEV_1$ was associated with both current and cumulative smoking ($B = -17.75$, $p = 0.0001$, and $B = -0.154$, $p = 0.033$, respectively), but not with age ($B = -0.071$, $p = 0.80$), duration of employment ($B = -0.021$, $p = 0.40$), or uranium exposure index ($B = -0.0090$, $p = 0.14$). Percent predicted FVC was associated with both current and cumulative smoking ($B = -8.73$, $p = 0.026$, and $B = -0.136$, $p = 0.050$, respectively), but not with age ($B = -0.053$, $p = 0.84$), duration of employment ($B = -0.012$, $p = 0.605$), or uranium exposure index ($B = 0.00044$, $p = 0.95$).

Neither restrictive nor obstructive PFT pattern was associated with a self-reported history of uranium exposure incidents (Table 5), high radiation badge readings, or having been told of overexposure to uranium or radiation (Table 6), and neither pattern was associated with percent MPLB (Table 7). Furthermore, neither percent predicted FVC nor $FEV_1/FVC$ was associated with any of the self-reported indicators of exposure (Table 8). Finally, none of the three pulmonary function parameters was associated with current percent MPLB ($r^2 < 0.01$, $p > 0.5$, in regression analyses for each).

One hundred thirty (89%) of the study participants were examined by chest x-ray (posterior-anterior view); none of the x-rays demonstrated increased interstitial lung markings suggestive of pneumoconiosis. Eleven (8.5%) of the x-rays showed evidence of pleural thickening, which was bilateral in seven cases. Although suggestive of past asbestos exposure, x-ray signs of pleural thickening were not associated with self-reported history of "regular or frequent" asbestos exposure. Some evidence of pleural thickening was present in one (7%) of 15 asbestos-exposed and 10 (9%) of 115 unexposed workers [relative risk (RR) = 0.77, 95% confidence interval (CI): 0.11 - 5.49], bilateral evidence was present in one (7%) of 15 exposed and 6 (5%) of 115 unexposed (RR = 1.28, 95% CI: 0.16 - 10.05).

Pleural thickening was not associated with the uranium exposure index (Table 4) or self-reported incidents of uranium exposure (Table 4). Although relative risks greater than 1 suggested possible associations between bilateral pleural thickening and the two other indicators of uranium exposure, the 95% confidence intervals for these measures were fairly wide and included 1 (Table 6).

D. Renal Effects

Eighteen (12%) of the participants reported ever having been told by a doctor that they had had a kidney stone; thirty (21%) persons reported having been told that they had had a kidney infection. Neither of these conditions was associated with the uranium exposure index, nor were recurrent or currently present kidney stones or infections (Table 4). Both participants who reported a current kidney stone currently had jobs in the low-exposure category, as did one of the four persons reporting a current kidney infection. The other three reporting a current kidney infection currently had jobs in the high-exposure category. (There were, respectively, 1, 35, 57, and 49 participants currently in the no-, low-, medium-, and high-exposure job categories.)

One hundred twenty-six (86%) of the participants provided specimens for one or more of the tests of renal function or damage. Concentrations of the various substances measured were not associated with current job exposure category (Table 9), duration of employment at the FMPC (Table 10), or the uranium exposure index (Tables 10 and 11). Neither were they associated with self-reported uranium exposure incidents, self-reported high radiation badge reading, or having been told of overexposure to uranium or radiation (Tables 5, 6, and 12a and b). [The apparently increasing relative risk of serum beta-2-microglobulin with increasing number of uranium exposure incidents (Table 4) could be an artifact attributable to the small number of abnormal results.] [Results for a particular test may have been omitted from a Table if (a) there was not a substantial number of abnormalities, and/or (b) the test was relatively non-specific for tubular dysfunction or damage, the expected effect of uranium.]

Additional comparisons that showed no consistent association between renal tests and exposure variables included: (a) test results dichotomized as abnormal (above the reference range) and normal (within or below the reference range) versus duration of employment (whether dichotomized at the median or at a suggestive point on the scatterplot); (b) test results dichotomized as in (a) versus uranium exposure index (whether dichotomized at the median or at a suggestive point on the scatterplot); (c) correlation (Pearson's) between creatinine-standardized renal test results (as a continuous variable) and duration of employment at the FMPC; and (d) renal test results (expressed as mean concentrations) for the three groups of participants who have always had jobs in the same (low-, medium-, high-) exposure category.

Beta-2-microglobulin is degraded in an acid environment, as, for example, in urine with a pH below 6. Since this circumstance can occur both in the bladder and in the collection container before the urine is processed, we evaluated this phenomenon as a potential source of error in the data. Only six urine specimens, however, had a pre-processing pH below 6; the mean beta-2-microglobulin concentration for these samples was 181 ug/l. The mean of the 103 beta-2-microglobulin analyses in urine with a pH of 6 was 226, and means of the 6 in urine with a pH of 7, and the 7 in urine with a pH of 8, were 221 and 172, respectively. Thus, even if the measured beta-2-microglobulin concentrations in the specimens with a pH less than 6 were erroneously low, the relatively small number of such cases could not have substantially affected the data analyses.

There was a high correlation among the urine concentrations of the three tubular enzymes (based on 113 sets of results: for N-acetyl glucosaminidase and gamma glutamyltranspeptidase, Pearson's $r = 0.298$, $p = 0.0014$; for N-acetyl glucosaminidase and alanine aminopeptidase, $r = 0.534$, $p = 0.0001$; for alanine aminopeptidase and gamma glutamyltranspeptidase, $r = 0.671$, $p = 0.0001$), but not between the urine concentrations of beta-2-microglobulin and retinol binding protein ($r = 0.043$, $p = 0.63$, 123 pairs). To identify individuals with the epidemiologically most convincing evidence of renal tubular dysfunction/damage, we listed those participants whose test results were in the highest 5% of the distribution of the creatinine-standardized urine concentrations of any of the three tubular enzymes, beta-2-microglobulin, or retinol binding protein. There were 21 participants with at least one such high value. Six had two or more such high values (Table 13). Two of the six reported numerous uranium exposure incidents, but these two were not among the three persons with more than two high test results. One person had a self-reported history of a high radiation badge reading, and another reported having been told of overexposure to uranium or radiation, but again these individuals were not among the three with more than two high test results.

No more than two of the six persons with two or more high test results had any one job or work area, past or present, in common. The median age of the six was 57 years; the median for the entire study group was 58 years. Curiously, the two participants with high values for all five tests were the oldest and youngest of the six. The median duration of employment at the FMPC was 31 years for the six; the median for the entire study group was 32 years. Neither of the two participants with high values for all five tests were above the median. (The individual age and seniority data have been omitted from Table 12 to prevent identification of the individuals.) Finally, the median uranium exposure index for the six workers was 663 exposure-months. The median for the entire study group was 665, and the 5th, 25th, 75th, 95th, and 99th percentiles were 285, 429, 1015, 1138, and 1149, respectively. Thus, the six workers with the most extreme renal test results did not appear to differ from the rest of the study group with respect to indicators of uranium exposure.

## V. DISCUSSION

This study demonstrated associations between indirect estimates of past or cumulative uranium exposure at the FMPC and both symptoms of shortness of breath and, even after accounting for cigarette smoking, spirometric evidence of obstructive pulmonary function. No such associations with renal effects were found. The study had several limitations, however. First, it was limited to current employees. Although, to our knowledge, no current workers were unable to participate because of pulmonary or renal disability, this may have been a reason for non-participation of some retired workers. Only a few of the recently retired workers accepted our invitation to participate in the study -- too few to be meaningfully included in the analysis. Furthermore, the study could not include information on deceased employees who had had pulmonary or renal problems.

Second, several of the indicators of uranium exposure were derived from the questionnaire responses and thus depended on the accuracy of the participants' memories. Furthermore, even the most objective measure of exposure used in the analyses -- a calculated cumulative uranium exposure index based on job category -- was only semi-quantitative. Although each participant had had individual urine uranium tests performed periodically since beginning work at the FMPC, the number of samples, timing, and reasons for testing (routine, exposure incident, follow-up, etc.) varied from person to person. This presented statistical analytical problems (see Future Actions, below). Also, the differences in solubility in body fluids of the various uranium compounds present at the FMPC result in different retention times in the lungs and different urine uranium levels (reflecting a different pattern of kidney exposure). Thus, similar urine uranium levels may not necessarily indicate biologically equivalent exposures.

Finally, the renal tests included in our study may not have been the most sensitive indicators of uranium nephrotoxicity. In retrospect, tubular reabsorption of phosphorus, urinary amino acid concentrations, or other tests of renal tubular function or damage might have proven to be more sensitive.

The urine uranium concentrations found during our survey suggest that current uranium exposures are within currently acceptable limits for occupationally exposed persons. The company data, however, suggest that exposures were higher in the past. Also, during the survey, none of the participants was involved in an "incident" of potentially higher exposure.

## VI. RECOMMENDATIONS

A. The medical monitoring program for workers exposed to uranium should include, in addition to the periodic determinations of uranium lung burden and urine uranium concentration, annual assessment of pulmonary and renal function:

1. Pulmonary function tests should be performed using standardized procedures.[5] This is necessary for (a) more accurate evaluation of an individual's pulmonary function, especially over time, and (b) analysis of group data.

2. Renal function tests should include (a) dipstick (pH, glucose, protein, occult blood) and microscopic urine analysis; (b) serum creatinine concentration, preferably with determination of creatinine clearance; and (c) some measure of renal tubular function, such as tubular reabsorption of phosphorus (which is calculated from concurrent serum and urine phosphate and creatinine concentrations).

3. Anyone with an abnormal test result, or a larger decrease in pulmonary or renal function than expected by age alone, should have appropriate medical evaluation.

B. A medical monitoring program should be available to anyone exposed to asbestos. Details of such a program are described in the OSHA asbestos standard (29 CFR 1910.1001).

## VII. FUTURE ACTIONS

1. NIOSH industrial hygienists will conduct an environmental evaluation of various exposures at the FMPC.

2. NIOSH epidemiologists will attempt to analyze the company's urine uranium monitoring data in conjunction with the NIOSH renal test results to determine if there is any association between renal effects and the amount of individually measured past uranium exposure.

## VIII. REFERENCES

1. National Institute for Occupational Safety and Health. Health hazard evaluation report no. HETA 85-111-1770. Cincinnati, OH: National Institute for Occupational Safety and Health, 1987.

2. Ferris BG. Epidemiology standardization project. II. Recommended respiratory disease questionnaire for use with adults and children in epidemiological research. Am Rev Respir Dis 1978;118:7S-53S.

3. American Thoracic Society. Chronic bronchitis, ashtma, and pulmonary emphysema. Am Rev Respir Dis 1962;85:762-8.

4. International Labour Organisation. Guidelines for the use of the ILO international classification of radiographs of pnenumoconioses, revised ed. Geneva: International Labour Organisation, 1980. [Occupational safety and health series, no. 22 (rev.)].

5. American Thoracic Society. ATS statement -- Snowbird workshop on standardization of spirometry. Am Rev Respir Dis 1979;119:831-8.

6. Knudson RJ, Slatin RC, Lebowitz MD, Burrows B. The maximal expiratory flow-volume curve. Normal standards, variability and effects of age. Am Rev Respir Dis 1976;113:587:600.

7. Lanese RR, Keller MD, Foley MF, Underwood EH. Differences in pulmonary function tests among whites, blacks, and American Indians in a textile company. J Occup Med 1978;20:39-44.

## IX. AUTHORSHIP AND ACKNOWLEDGEMENTS


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TABLE 1

Blood and Urine Tests

FEED MATERIALS PRODUCTION CENTER
FERNALD, OHIO
HETA 83-144

| Test | Analytical Method | Reference Range |
| --- | --- | --- |
| Blood (serum) | | |
| Beta-2-microglobulin | Pharmacia Diagnostics Phadebas Beta-2-Microglobulin Test Kit, Uppsala, Sweden | age ≤59: <2400 ug/l<br>age >59: <3000 ug/l |
| Retinol binding protein | Radial immunodiffusion Kits, Calbiochem-Behring, LaJolla, CA 92037 | 3 - 6 mg/dl |
| Albumin | Dupont ACA Chemistry Manual, Wilmington, Delaware, 1983 | 3.4 - 5.0 g/dl |
| Total protein | Dupont ACA Chemistry Manual, Wilmington, Delaware, 1983 | 6.4 - 8.2 g/dl |
| Creatinine | Dupont ACA Chemistry Manual, Wilmington, Delaware, 1983 | male: 0.8 - 1.3 mg/dl<br>female: 0.6 - 1.0 mg/dl |
| Urine | | |
| Uranium | Health and Safety Manual, 26th Edition of EML Procedure Manual, 1983, Department of Energy | <5 ug/l* |
| Beta-2-microglobulin | Pharmacia Diagnositics Phadebas Beta-2-Microglobulin Test Kit, Uppsala, Sweden | <300 ug/l |
| Retinol binding protein | Radial Immunodiffusion Kits, Calbiochem-Behring, LaJolla, CA 92037 | 0.03 - 0.19 ug/ml |

TABLE 1 (continued)

| Test | Analytical Method | Reference Range |
|---|---|---|
| N-acetyl glucosaminidase | D. Leaback, P. Walker, Biochem. J., 78:151-156, 1961 | 0.17 - 3.50 U/l |
| Gamma glutamyl transpeptidase | Calbiochem-Behring Gamma-GT Reagent Cat. No. 869813, Calbiochem-Behring Corp., LaJolla, CA 92037 | 5.47 - 50.88 U/l |
| Alanine aminopeptidase | K. Jung and D. Scholz, Clin. Chem 26:1251-1254, 1980 | 1.80 - 8.91 U/l |
| Creatinine | DuPont ACA Chemistry Manual Wilmington, Delaware, 1983 | male: 0.6 - 2.5 g/24 hr<br>female: 0.6 - 1.5 g/24 hr |
| Total Protein | Dupont ACA Chemistry Manual Wilmington, Delaware, 1983 | <136 mg/l |
| Albumin | B. Fielding, D. Price, and C. Houlton, Enzyme Immunoassay for Urinary Albumin, Clin. Chem. 29: 355-357 | 33.2 mg/l |
| Specific gravity | J. Roth, Renal Function Tests. In: fundamentals of clinical chemistry, edited by Norbert Tietz, W.B. Saunders Co., Philadelphia, PA, 1976, pp 1005-1008 | 1.001 - 1.035 |
| pH | Dipstick | 4.6 - 8.0 |

* - Using a more sensitive analytical method, the reference range for the general population would be <1 ug/l.

TABLE 2

Self-reported Workplace Exposures

FEED MATERIALS PRODUCTION CENTER
FERNALD, OHIO
HETA 83-144
SEPTEMBER 16-27, 1985

| Exposure | Number of Employees Exposed and (Percent* of Participants) | | |
|---|---|---|---|
| | Regularly or Frequently | Occasionally | Infrequently or Never |
| Uranium | 93 (64) | 41 (28) | 11 (8) |
| Thorium | 25 (17) | 69 (48) | 50 (35) |
| Nitric acid | 49 (34) | 67 (46) | 29 (20) |
| Hydrogen fluoride | 31 (21) | 58 (40) | 56 (39) |
| Ammonia | 36 (25) | 78 (54) | 31 (21) |
| Tributyl phosphate | 16 (11) | 46 (32) | 80 (56) |
| Grinding or cutting oils or coolants | 28 (19) | 52 (36) | 64 (44) |
| Solvents (other than nitric acid or kerosene/tributyl phosphate) | 22 (15) | 48 (33) | 74 (51) |
| Asbestos | 17 (12) | 38 (26) | 89 (62) |

* - Row total percentages may not add to 100 because of rounding.

TABLE 3

Uranium Lung Burden and Self-reported Exposure Indicators

FEED MATERIALS PRODUCTION CENTER
FERNALD, OHIO
HETA 83-144
SEPTEMBER 16-27, 1985

| Exposure Indicator | Percent Maximum Permissible Lung Burden | | |
|---|---|---|---|
| | Mean | Standard error of the mean | Number of participants |
| Uranium exposure incidents | | | |
| ≥1 | 15 | 2.2 | 29 |
| 0 | 14 | 3.6 | 17 |
| ≥20 | 14 | 4.0 | 13 |
| <20 | 15 | 2.2 | 33 |
| High radiation badge reading | | | |
| Yes | 18[A] | 3.9 | 15 |
| No | 12[A] | 2.0 | 33 |
| Told overexposed to uranium or radiation | | | |
| Yes | 23[B] | 5.4 | 10 |
| No | 12[B] | 1.8 | 38 |

A - $p = 0.11$ (t-test, variances equal).
B - $p = 0.07$ (t-test, variances unequal).

TABLE 4

Pulmonary Outcomes and Uranium Exposure Index (see text)

FEED MATERIALS PRODUCTION CENTER
FERNALD, OHIO
HETA 83-144
SEPTEMBER 16-27, 1985

| Condition[1] | Condition Present | | Condition Absent | |
|---|---|---|---|---|
| | Number | Exposure-months, Mean and (S.E.M)[2] | Number | Exposure-months, Mean and (S.E.M.) |
| Chronic cough | 14 | 695 (68.0) | 132 | 695 (25.4) |
| Chronic bronchitis | 11 | 776 (82.8) | 135 | 689 (24.9) |
| Shortness of breath | | | | |
| ≥ grade 1 | 47 | 688 (38.6) | 98 | 702 (30.3) |
| ≥ grade 2 | 18 | 678 (67.7) | 126 | 697 (25.7) |
| ≥ grade 3 | 10 | 731 (91.1) | 134 | 695 (24.9) |
| ≥ grade 4 | 9 | 747 (100.6) | 135 | 691 (24.7) |
| Pulmonary function pattern | | | | |
| Restrictive[3] | 14 | 801[A] (75.1) | 97 | 664[A] (28.5) |
| Obstructive[3] | 23 | 846[B] (54.2) | 88 | 638[B] (29.3) |
| X-ray abnormalities | | | | |
| Pleural thickening | 11 | 816 (85.5) | 119 | 675 (25.8) |
| Bilateral pleural thickening | 7 | 831 (111.0) | 123 | 678 (25.4) |
| History of kidney stone | 18 | 625 (58.9) | 128 | 705 (25.8) |
| Recurrent or continuing | 3 | 484 (66.5) | 143 | 700 (24.2) |
| Currently present | 2 | 518 (99.3) | 144 | 698 (24.1) |
| History of Kidney infection | 30 | 627 (44.5) | 116 | 712 (27.6) |
| Recurrent or continuing | 10 | 587 (51.7) | 136 | 703 (25.2) |
| Currently present | 4 | 587 (114.6) | 142 | 698 (24.3) |

1 - See text for definition.
2 - Standard error of the mean.
3 - Includes mixed restrictive/obstructive pattern.
A - $p = 0.093$ (t-test, variances equal).
B - $p = 0.014$ (t-test, variances equal).

TABLE 5

Health Parameters and Self-reported Uranium Exposure Incidents

FEED MATERIALS PRODUCTION CENTER
FERNALD, OHIO
HETA 83-144
SEPTEMBER 16-27, 1985

| Condition[1] | >1 Incident | 0 Incidents | Relative risk | 95% Confidence Interval | >20 Incidents | <20 Incidents | Relative risk | 95% Confidence Interval |
|---|---|---|---|---|---|---|---|---|
| Chronic cough | 9/78 (12)[2] | 4/63 (6) | 1.82 | 0.60 - 5.51 | 4/38 (11) | 9/103 (9) | 1.20 | 0.39 - 3.71 |
| Chronic bronchitis | 9/78 (12) | 1/63 (2) | 7.27 | 1.32 - 38.99 | 5/38 (13) | 5/103 (5) | 2.71 | 0.86 - 8.57 |
| Shortness of breath | | | | | | | | |
| ≥ grade 1 | 27/78 (35) | 17/62 (27) | 1.26 | 0.76 - 2.09 | 18/38 (47) | 26/102 (25) | 1.86 | 1.14 - 3.04 |
| ≥ grade 2 | 13/77 (17) | 4/62 (6) | 2.62 | 0.95 - 7.22 | 8/37 (21) | 9/102 (9) | 2.45 | 0.99 - 5.83 |
| ≥ grade 3 | 8/77 (11) | 1/62 (2) | 6.44 | 1.12 - 37.2 | 6/37 (16) | 3/102 (3) | 5.51 | 1.67 - 18.2 |
| ≥ grade 4 | 9/77 (11) | 1/62 (2) | 6.44 | 1.12 - 37.2 | 6/37 (14) | 4/102 (4) | 3.45 | 1.04 - 11.4 |
| Pulmonary function pattern | | | | | | | | |
| Restrictive[3] | 9/61 (15) | 5/49 (10) | 1.45 | 0.52 - 4.01 | 4/29 (14) | 10/81 (12) | 1.12 | 0.38 - 3.31 |
| Obstructive[3] | 13/61 (21) | 10/49 (20) | 1.04 | 0.50 - 2.18 | 5/29 (17) | 18/81 (22) | 0.78 | 0.32 - 1.88 |
| X-ray abnormalities | | | | | | | | |
| Pleural thickening | 4/70 (6) | 6/59 (10) | 0.56 | 0.17 - 1.87 | 2/34 (6) | 8/95 (8) | 0.70 | 0.16 - 3.09 |
| Bilateral pleural thickening | 2/70 (3) | 4/59 (7) | 0.42 | 0.08 - 2.12 | 1/34 (3) | 5/95 (5) | 0.56 | 0.07 - 4.45 |
| Selected Renal test abnormalities[4] | | | | | | | | |
| Serum | | | | | | | | |
| Beta-2-microglobulin | 2/69 (3) | 1/55 (2) | 1.59 | 0.15 - 16.86 | 2/34 (6) | 1/90 (1) | 5.29 | 0.63 - 44.4 |
| Retinol binding protein | 18/69 (26) | 11/55 (20) | 1.30 | 0.68 - 2.52 | 11/34 (32) | 18/90 (20) | 1.62 | 0.84 - 3.11 |
| Urine | | | | | | | | |
| Beta-2-microglobulin | 7/66 (11) | 10/57 (18) | 0.60 | 0.25 - 1.47 | 3/31 (10) | 14/92 (15) | 0.64 | 0.20 - 2.01 |
| Retinol binding protein | 4/67 (6) | 9/58 (16) | 0.38 | 0.13 - 1.13 | 3/33 (9) | 10/92 (11) | 0.84 | 0.25 - 2.84 |
| Alanine aminopeptidase | 8/61 (13) | 10/51 (20) | 0.67 | 0.29 - 1.57 | 6/30 (20) | 12/82 (15) | 1.37 | 0.56 - 3.36 |

1 - See text for definitions.
2 - Number with condition/number in category and (percent).
3 - Includes mixed restrictive/obstructive pattern.
4 - Only concentrations above the reference ranges (see Table 1) are considered abnormal for the purpose of these analyses.

TABLE 6

Health Parameters and Self-reported Exposure Indicators

FEED MATERIALS PRODUCTION CENTER
FERNALD, OHIO
HETA 83-144
SEPTEMBER 16-27, 1985

| Condition[1] | Ever Told Radiation Badge Showed Excessive Exposure | | | | Ever Told Overexposed to Uranium or Radiation | | | |
|---|---|---|---|---|---|---|---|---|
| | Yes | No | Relative Risk | 95% Confidence Interval | Yes | No | Relative Risk | 95% Confidence Interval |
| Chronic cough | 2/29 (7)[2] | 12/117 (10) | 0.67 | 0.16 - 2.78 | 2/22 (9) | 12/124 (10) | 0.94 | 0.23 - 3.88 |
| Chronic bronchitis | 2/29 (7) | 9/117 (8) | 0.90 | 0.21 - 3.92 | 2/22 (9) | 9/124 (7) | 1.25 | 0.29 - 5.47 |
| Shortness of breath | | | | | | | | |
| ≥ grade 1 | 11/29 (38) | 36/116 (31) | 1.22 | 0.70 - 2.13 | 9/22 (41) | 38/123 (31) | 1.32 | 0.73 - 2.41 |
| ≥ grade 2 | 5/29 (17) | 13/115 (9) | 1.53 | 0.58 - 3.99 | 5/22 (23) | 13/122 (11) | 2.13 | 0.83 - 5.49 |
| ≥ grade 3 | 3/29 (10) | 7/115 (6) | 1.70 | 0.47 - 6.20 | 3/22 (14) | 7/122 (6) | 2.38 | 0.67 - 8.46 |
| ≥ grade 4 | 2/29 (7) | 7/115 (6) | 1.13 | 0.25 - 5.21 | 2/22 (9) | 7/122 (6) | 1.58 | 0.35 - 7.20 |
| Pulmonary function pattern | | | | | | | | |
| Restrictive[3] | 3/23 (13) | 11/88 (13) | 1.04 | 0.32 - 3.42 | 5/19 (26) | 15/111 (14) | 1.95 | 0.78 - 4.87 |
| Obstructive | 4/23 (17) | 19/88 (22) | 0.81 | 0.31 - 2.11 | 6/19 (32) | 24/111 (22) | 1.46 | 0.67 - 3.20 |
| X-ray abnormalities | | | | | | | | |
| Pleural thickening | 3/25 (12) | 8/105 (8) | 1.58 | 0.45 - 5.58 | 3/19 (16) | 8/111 ( 7) | 2.19 | 0.63 - 7.59 |
| Bilateral pleural thickening | 2/25 (8) | 5/105 (5) | 1.68 | 0.35 - 8.18 | 2/19 (11) | 5/111 (5) | 2.34 | 0.49 - 11.06 |
| Selected renal tests, abnormalities[4] | | | | | | | | |
| Serum | | | | | | | | |
| Beta-2-microglobulin | 0/23 (0) | 3/102 (3) | 0 | -- | 1/18 (6) | 2/107 ( 2) | 2.97 | 0.31 - 28.7 |
| Retinol binding protein | 5/23 (22) | 25/102 (25) | 0.89 | 0.38 - 2.05 | 7/18 (39) | 23/107 (22) | 1.81 | 0.87 - 3.75 |
| Urine | | | | | | | | |
| Beta-2-microglobulin | 5/24 (21) | 12/100 (12) | 1.74 | 0.66 - 4.54 | 2/17 (12) | 15/107 (14) | 0.84 | 0.21 - 3.31 |
| Retinol binding protein | 2/24 (8) | 11/102 (11) | 0.77 | 0.19 - 3.22 | 1/18 (6) | 12/108 (11) | 0.50 | 0.08 - 3.35 |
| Alanine aminopeptidase | 3/22 (14) | 15/91 (16) | 0.83 | 0.27 - 2.59 | 3/17 (18) | 15/96 (16) | 1.13 | 0.36 - 3.53 |

1 - See text for definitions.
2 - Number with condition/number in category and (percent).
3 - Includes mixed restrictive/obstructive pattern.
4 - Only concentrations above reference range (see Table 1) are considered abnormal for the purpose of these analyses.

TABLE 7

Respiratory Outcomes and Percent Maximum Permissible Uranium Lung Burden (%MPLB)

FEED MATERIALS PRODUCTION CENTER
FERNALD, OHIO
HETA 83-144
SEPTEMBER 16-27, 1985

| Outcome[1] | Outcome present: Yes | Outcome present: No |
|---|---|---|
| Chronic cough | 9 (2.3) [5][2] | 15 (13.6) [43] |
| Chronic bronchitis | 17 (7.0) [5] | 14 (2.0) [43] |
| Shortness of breath | | |
| ≥ grade 1 | 11 (2.8) [16] | 16 (2.4) [32] |
| ≥ grade 2 | 16 (6.6) [5] | 14 (2.0) [42] |
| ≥ grade 3 | 12 (8.1) [3] | 14 (2.0) [44] |
| ≥ grade 4 | 12 (8.1) [3] | 14 (2.0) [44] |
| Pulmonary function pattern | | |
| Restrictive[3] | 12 (6.5) [5] | 13 (2.0) [32] |
| Obstructive[3] | 12 (2.9) [12] | 14 (2.4) [25] |
| X-ray abnormalities | | |
| Pleural thickening | 16 (5.5) [5] | 15 (2.2) [38] |
| Bilateral pleural thickening | 19 (9.4) [3] | 15 (2.1) [40] |

1 - See text for definitions.
2 - Mean %MPLB, standard error of the mean (in parentheses), and (in brackets) number of participants in category.
3 - Includes mixed restrictive/obstructive pattern.

TABLE 8

Pulmonary Function Abnormalities and Self-reported Exposure Indicators

FEED MATERIALS PRODUCTION CENTER
FERNALD, OHIO
HETA 83-144
SEPTEMBER 16-27, 1985

| Exposure Indicator | Number of Participants | Percent predicted FVC | $FEV_1/FVC$ |
|---|---|---|---|
| Uranium exposure incidents | | | |
| ≥1 | 61 | 97 (1.9)* | 74 (1.2) |
| 0 | 50 | 96 (2.2) | 76 (1.3) |
| ≥20 | 29 | 95 (2.3) | 75 (1.8) |
| <20 | 82 | 97 (1.8) | 75 (1.0) |
| High radiation badge reading | | | |
| Yes | 23 | 97 (3.0) | 75 (1.7) |
| No | 89 | 97 (1.6) | 75 (1.0) |
| Told overexposed to uranium or radiation | | | |
| Yes | 15 | 94 (4.1) | 75 (2.2) |
| No | 97 | 97 (1.5) | 75 (1.0) |

*Mean and (standard error of the mean)

TABLE 9

Selected Renal Tests and Current Job Exposure Category[1]

FEED MATERIALS PRODUCTION CENTER
FERNALD, OHIO
HETA 83-144
SEPTEMBER 16-27, 1985

| Test | Job Exposure Category | | |
|---|---|---|---|
| | Low | Medium | High |
| Serum | | | |
| Beta-2-microglobulin | 1500 (74) [34][A] | 1467 (56) [48] | 1555 (64) [43] |
| Retinol binding protein | 5.4 (0.19) [34] | 5.2 (0.12) [48] | 5.4 (0.17) [43] |
| Creatinine | 1.02 (0.023) [33] | 0.97(0.026) [47] | 0.93 (0.028) [43] |
| Urine | | | |
| Beta-2-microglobulin | 239 (13.2) [33] | 214 (8.0) [49] | 216 (9.0) [42] |
| Retinol binding protein | 0.14 (0.012) [34] | 0.094 (0.0077) [49] | 0.10 (0.0088) [43] |
| N-acetyl glucosaminidase | 1.14 (0.16) [33] | 0.88 (0.061) [48] | 0.85 (0.10) [42] |
| Gamma glutamyltranspeptidase | 23.8 (1.77) [31] | 23.0 (1.78) [44] | 20.9 (1.90) [38] |
| Total protein | 26.2 (7.4) [32] | 28.6 (6.4) [47] | 28.5 (7.8) [41] |
| Albumin | 6.58 (1.07) [33] | 6.19 (0.85) [48] | 5.11 (0.51) [41] |
| Specific gravity | 1.014 (0.0011) [33] | 1.014 (0.0009) [48] | 1.014 (1.011) [41] |
| Alanine aminopeptidase | 7.28 (0.55) [31] | 5.91 (0.35) [44] | 6.53 (0.52) [38] |
| Urine, creatinine-standardized[2] | | | |
| Beta-2-microglobulin | 274 (35.2) [32] | 329 (67.3) [48] | 313 (33.2) [40] |
| Retinol binding protein | 155 (24.1) [33] | 153 (42.4) [48] | 152 (18.6) [41] |
| N-acetyl glucosaminidose | 1.14 (0.17) [32] | 1.14 (0.14) [48] | 1.06 (0.13) [41] |
| Gamma glutamyl transpeptidase | 23.4 (1.3) [31] | 25.6 (2.5) [44] | 23.9 (1.7) [38] |
| Total protein | 17.4 (5.1) [32] | 21.8 (5.3) [47] | 20.1 (5.4) [41] |
| Albumin | 6.10 (0.96) [33] | 7.56 (1.31) [48] | 6.18 (0.79) [41] |
| Alanine aminopeptidose | 7.35[B] (0.53) [31] | 7.87[B] (1.14) [44] | 8.16[B] (0.68) [38] |

1 - See text for explanation.
A - Mean (see Table 1 for units), standard error of the mean (in parentheses), and (in brackets) number of participants in category.
2 - Concentrations expressed as mass or activity units (see Table 1) per gram of creatinine.
B - Differences in means not significant at alpha = 0.05, Ducan's multiple-range test.

TABLE 10

Selected Renal Test Results, Duration of Employment, and Uranium Exposure Index

FEED MATERIALS PRODUCTION CENTER
FERNALD, OHIO
HETA 83-144
SEPTEMBER 16-27, 1985

| Test | Duration of employment (months) | | Uranium exposure index (exposure-months) | |
|---|---|---|---|---|
| | Normal | Abnormal | Normal | Abnormal |
| Serum | | | | |
| Beta-2-microglobulin | 347 (7.4) [122][A] | 335 (62.0) [3] | 679 (25.5) [122] | 802 (165) [3] |
| Retinol binding protein | 342 (8.8) [95] | 363 (12.2) [30] | 666 (27.2) [95] | 736 (60.0) [30] |
| Urine | | | | |
| Beta-2-microglobulin | 345 (8.1) [107] | 357 (17.7) [17] | 678 (26.9) [107] | 676 (72.1) [17] |
| Retinol binding protein | 343[B] (8.2) [113] | 373[B] (5.5) [13] | 695 (26.8) [113] | 520 (58.4) [13] |
| Alanine aminopeptidase | 342[C] (9.1) [95] | 377[C] (4.6) [18] | 684 (29.5) [95] | 688 (73.1) [18] |

A - Mean, standard error of the mean (in parentheses), and (in brackets) number of participants in category.
B - $p = 0.23$ (t-test, variances unequal).
C - $p = 0.0008$ (t-test, variances unequal).

TABLE 11

Correlations between Selected Renal Tests and Uranium Exposure Index[1]

FEED MATERIALS PRODUCTION CENTER
FERNALD, OHIO
HETA 83-144
SEPTEMBER 16-27, 1985

| Test | Number of Participants | Correlation (Pearson's) r | p |
|---|---|---|---|
| Serum | | | |
| Beta-2-microglobulin | 125 | 0.11 | 0.21 |
| Retinol binding protein | 125 | 0.16 | 0.07 |
| Urine[2] | | | |
| Beta-2-microglobulin | 120 | -0.064 | 0.48 |
| Retinol binding protein | 122 | -0.093 | 0.31 |
| N-acetyl glucosaminidase | 121 | -0.091 | 0.32 |
| Gamma glutamyltranspeptidase | 113 | 0.002 | 0.99 |
| Total protein | 120 | 0.067 | 0.47 |
| Albumin | 122 | -0.067 | 0.46 |
| Alanine aminopeptidase | 113 | -0.006 | 0.95 |

1 - See text.
2 - Concentrations (see Table 1) expressed as mass or activity units per gram of creatinine.

TABLE 12a

Selected Renal Test Results
and Self-Reported Exposure Indicators

FEED MATERIALS PRODUCTION CENTER
FERNALD, OHIO
HETA 83-144
SEPTEMBER 16-27, 1985

| | Parameter Mean*, (Standard Error of the Mean), and [Number of Participants in Category] | | | |
|---|---|---|---|---|
| | Serum | | Urine | |
| Exposure Indicator | Beta-2-microglobulin | Retinol binding protein | Beta-2-microglobulin | Retinol binding protein |
| Uranium exposure incidents | | | | |
| ≥1 | 1456 (47) [69] | 5.39 (0.13) [69] | 218 (7.7) [66] | 0.104 (0.0068) [67] |
| 0 | 1558 (58) [55] | 5.27 (0.12) [55] | 226 (8.5) [57] | 0.117 (0.0090) [58] |
| ≥20 | 1520 (82) [34] | 5.45 (0.21) [34] | 213 (11.7) [31] | 0.106 (0.0098) [33] |
| <20 | 1495 (40) [90] | 5.29 (0.09) [90] | 224 (6.6) [92] | 0.111 (0.0067) [92] |
| High radiation badge reading | | | | |
| Yes | 1492 (80) [23] | 5.10 (0.22) [23] | 222 (15.9) [24] | 0.108 (0.0116) [24] |
| No | 1509 (41) [102] | 5.40 (0.97) [102] | 221 (5.9) [100] | 0.109 (0.0064) [102] |
| Told overexposed to uranium or radiation | | | | |
| Yes | 1473 (105) [18] | 5.56 (0.29) [18] | 225 (13.7) [17] | 0.112 (0.014) [18] |
| No | 1511 (39) [107] | 5.31 (0.09) [107] | 221 (6.2) [107] | 0.109 (0.0061) [108] |

* - See Table 1 for units.

TABLE 12b

Selected Renal Test Results
and Self-reported Exposure Indicators

FEED MATERIALS PRODUCTION CENTER
FERNALD, OHIO
HETA 83-144
SEPTEMBER 16-27, 1985

| Exposure Indicator | Parameter Mean*, (Standard Error of the Mean), and [Number of Participants in Category] | | | | |
|---|---|---|---|---|---|
| | Urine | | | | |
| | N-acetyl glucosaminidase | Gamma glutamyl transpeptidase | Total Protein | Albumin | Alanine amino-peptidase |
| Uranium exposure incidents | | | | | |
| ≥1 | 0.934 (0.090) [66] | 22.7 (1.49) [61] | 27.6 (5.87) [63] | 5.60 (0.45) [65] | 6.38 (0.37) [61] |
| 0 | 0.960 (0.082) [56] | 22.4 (1.53) [51] | 28.8 (5.91) [56] | 6.40 (0.89) [56] | 6.68 (0.41) [51] |
| ≥20 | 1.066 (0.161) [32] | 23.9 (2.10) [30] | 34.6 (9.77) [30] | 5.75 (0.65) [31] | 7.03 (0.61) [30] |
| <20 | 0.903 (0.060) [90] | 22.1 (1.23) [82] | 26.0 (4.48) [89] | 6.05 (0.60) [90] | 6.33 (0.30) [82] |
| High radiation badge reading | | | | | |
| Yes | 0.905 (0.149) [24] | 21.9 (2.21) [22] | 27.9 (11.1) [22] | 5.88 (1.48) [23] | 6.58 (0.50) [22] |
| No | 0.947 (0.067) [99] | 22.7 (1.20) [91] | 27.9 (4.41) [98] | 5.95 (0.48) [99] | 6.48 (0.32) [91] |
| Told overexposed to uranium or radiation | | | | | |
| Yes | 0.892 (0.163) [18] | 2.52 (2.92) [17] | 31.9 (12.3) [18] | 6.77 (0.92) [18] | 7.14 (0.87) [17] |
| No | 0.947 (0.066) [105] | 22.0 (1.13) [96] | 27.2 (4.36) [102] | 5.79 (0.53) [104] | 6.38 (0.28) [96] |

* - See Table 1 for units.

TABLE 13

Correlations between Summary Estimates[1] of
Cumulative Uranium Exposure and
Selected Renal Tests Results[2]

FEED MATERIALS PRODUCTION CENTER
FERNALD, OHIO
HETA 83-144
SEPTEMBER 16-27, 1985

| Renal test | Number of Participants | Estimate of Exposure: Sum of Annual Medians r* | Sum of Annual Medians p | Sum of Annual Maximums r | Sum of Annual Maximums p |
|---|---|---|---|---|---|
| Beta-2-microglobulin | 119 | 0.27 | 0.10 | 0.15 | 0.098 |
| Retinol binding protein | 121 | 0.04 | 0.70 | 0.07 | 0.47 |
| N-acetyl glucosaminidase | 120 | 0.01 | 0.88 | 0.11 | 0.25 |
| Albumin | 121 | -0.05 | 0.55 | 0.02 | 0.84 |

1 - See text.
2 - Creatinine-standardized urine concentrations.
* - Pearson's correlation coefficient.

TABLE 14

Participants Having Results of 2 or More Urine Tests in the Highest 5% of the Distribution of Creatinine-standardized Concentrations

FEED MATERIALS PRODUCTION CENTER
FERNALD, OHIO
HETA 83-144
SEPTEMBER 16-27, 1985

| Participant | High Test Result | | | | | Number of Self-reported Uranium Exposure Incidents | Self-reported History of High Radiation Badge Reading | Ever told of Overexposure to Uranium or Radiation | Uranium Exposure Index Exposure-months |
|---|---|---|---|---|---|---|---|---|---|
| | B2M* | RBP* | NAG* | GGT* | AAP* | | | | |
| A | Yes | Yes | Yes | Yes | Yes | 0 | No | No | 775 |
| B | Yes | Yes | Yes | Yes | Yes | 1 | No | No | 217 |
| C | No | Yes | Yes | No | Yes | 0 | No | No | 552 |
| D | Yes | No | No | Yes | No | ≥100 | No | Yes | 1147 |
| E | No | No | No | Yes | Yes | 0 | No | No | 446 |
| F | No | Yes | No | No | Yes | ≥100 | Yes | No | 1013 |

*B2M = beta-2-microglobulin, RBP = retinol binding protein, NAG = N-acetylglucosaminidase, GGT = gamma glutamyl transpeptidase, AAP = alanine aminopeptidase

# APPENDIX A

## Uranium Exposure Categories (See Text for Explanation)

Feed Materials Production Center
Fernald, Ohio
HETA 83-144

Note: Jobs never held by any of the study participants might not be included in this list. A close grouping of job titles indicates either different titles (both official and informal) for the same job or jobs that are similar with respect to potential uranium exposure.

<u>NO EXPOSURE</u>

Nuclear Material Technology Control Administrator

Accounting Clerk I
Accounting Clerk II
Chief Clerk (in Control Prod)
Clerk II (in Records Prod)
Clerk IIA
Clerk III (in Control Prod, AP Adm, Records Prod, Acct)
Clerk IV
Invoice Clerk
Typist Clerk I

Secretary
Steno-Secretary
Stenographer

Utility Man-Cafeteria

<u>LOW EXPOSURE</u>

Section Leader II, except as listed under medium exposure
Technical Assistant, except as listed under medium exposure
Technician "B", except as listed under medium exposure
Technician I (in Anal Tech)
Technician II (in Anal Tech)
Technician III (in Anal Tech)
Technologist I, except as listed under medium exposure
Technologist III (in Anal Tech)

Oiler

Coal Handler

Assistant Pumpman

LOW EXPOSURE (continued)

Data Reporting Coordinator

Chief, Nuclear Safety

Scheduler

Storekeeper

Bulldozer Operator
Coal Operator

Tool Room Machinist

Police Sergeant

Senior Engineer
Senior Staff Engineer

Chief Clerk, except as listed under no exposure
Clerk II, except as listed under no exposure
Clerk III, except as listed under no exposure
Clerk V

Power Plant Oiler

Water Plant Operator

Stores Warehouse Attendant
Stores Warehouseman
Warehouseman

Stationary Engineer

Operator "A" (Pumpman)
Pump Operator
Pumpman
Pumpman Operator

Porter

Boiler operator helper (in PP&U, P&WT Engr, PP Engr, Engr)
Fireman's Helper

Assistant Fireman

LOW EXPOSURE (continued)

Boiler operator
Boiler operator helper (other than in PP&U, P&WT Engr, PP Engr, Engr)
Fireman

Security Police
Security Police Officer

Checker
Material Checker

MEDIUM EXPOSURE

Area Maintenance Supervisor
Area Supervisor
Department Superintendent
Department Supervisor
General Supervisor
Group Supervisor
Maintenance Supervisor
Night Shift Supervisor
Production Supervisor
Stores Supervisor
Supervisor
Warehouse Supervisor
Water Plant Supervisor

Carpenter
Carpenter Apprentice

Degreaser
Degreaser Helper

Ind. Truck Operator
Ind. Truck Operator "A"
Operator "A" (Ind. Truck)

Furnace Operator Heater

Gauge Set-up

Heavy Equipment Operator

Inspector
Operator "A" (Inspector)
Operator "B" (Inspector)
Operator "C" (Inspector)

MEDIUM EXPOSURE (continued)

Chief Technician
Tech Asst (Adm Prod, Met Tech, PT Tech, Adm Tech, Chem Tech, Anal Tech)
Technician "B" (in Met Tech)
Technician "C"

Technician I (in H & S)
Technician II (in Met Tech, H & S)
Technician III (in Adm Tech, Met Tech, Prod Tech)
Technologist "A"
Technologist "C"
Technologist I (in PT Tech, Chem Tech, H & S)
Techologist II
Technologist III, except as listed under low exposure

Laundry Worker
Laundryman

Motor Vehicle Operator

Fire and Safety Inspector

Machinist

Assistant Water Plant Operator

Helper
Mill Hand
Mill Helper
Mill Man

Rigger
Rigger Trainee

Machine Set-up
Set-up Man

Laborer (in Trans Prod; 3, 6, & 9 Prod)
Operator "A" (6 Prod)
Operator "B" (other than Inspection), except as listed under high exposure
Operator "C" (other than Inspection and Lab)
Operator "C" (Laborer)

Stamper

Packer

Straightener
Straightener Operator

MEDIUM EXPOSURE (continued)

Hook-up Man

Crop Shear Operator

Cooling Bed Operator

Electrician
Electrician Apprentice (1st Year)
Electrician Apprentice (2nd Year)

Operator "A" (FI Tech)

Section Leader I
Section Leader II (in Chem Tech, PT Tech, Met Tech)

Area Foreman
Area Maintenance Foreman
Craft Foreman
Foreman
Maintenance Foreman

Machine Operator

Tool Maker

Recorder

Guide Setter "B"

Looper Operator

Operator "C" (Lab)

HIGH EXPOSURE

Chemical Operator
Chemical Operator Helper
Chemical Process Trainee
Leaderman

Laborer (in 1, 5, & 8 Prod)
Operator "A" (other than MTOH), except as noted under medium and low exposure
Operator "B" (PP Tech, 5 & 9 Prod)

HIGH EXPOSURE (continued)

Saw Operator

Laborer (in PLP Prod)

Mason

Millwright
Millwright Apprentice 1st, 2nd, 3rd, & 4th
Trades Helper (Millwright)

Instrument Mechanic
Instrument Mechanic Apprentice (1st year)
Trades Helper (Instrument Mechanic)

Dry Cleaner

Painter

Pipefitter
Pipefitter Apprentice

Utilities & Utilities Engineer

Graphite Shop Machinist

Decontaminator

Welder

DEPARTMENT OF HEALTH & HUMAN SERVICES

Public Health Service

APPENDIX B

Centers for Disease Control
National Institute for
Occupational Safety & Health
Robert A. Taft Laboratories
4676 Columbia Parkway
Cincinnati, OH 45226-1998

June 22, 1988
HETA 83-144

[redacted]
Site Manager
Feed Materials Production Center
c/o Westinghouse Materials Company of Ohio
P.O. Box 39158
Cincinnati, Ohio 45239

Dear [redacted]:

In July 1987, we issued a report describing the findings of our 1985 medical study of workers at the Feed Materials Production Center. In that report we said that we would analyze the company's urine uranium monitoring data in conjunction with the NIOSH renal (kidney) test results to determine if there is any association between measures of current renal function or damage and past uranium exposure, as measured by periodic determination of urine uranium concentration during the participants' employment at the FMPC. This letter, copies of which are being sent to company and union representatives, as well as other interested parties, reports the results of that analysis.

For each study participant we calculated two summary estimates of cumulative uranium exposure based solely on the historical urine uranium data: the sum of the median urine uranium levels for each calendar year of work at the FMPC, and the sum of the maximum levels for each year. To calculate the two summary estimates of a participant's cumulative uranium exposure, all urine uranium determinations for that person were used; this entailed an average of 100 determinations per person. Neither summary estimate of cumulative urine uranium exposure was associated with creatinine-standardized urine concentration of beta-2-microglobulin, retinol binding protein, N-acetylglucosamnidase, or albumin (Table A). (One person, who had a very low urine creatinine concentration, and thus very high creatinine-standardized concentrations of all four substances, was excluded from these analyses.)

These results do not change the conclusion regarding the lack of an association between renal effects and estimates of past urine uranium exposure. Although the estimates of uranium exposure used in this analysis are perhaps more objective than those used in the previous report, the two summary estimates may not have accurately and consistently reflected an individual's total exposure experience. Although each participant had had individual urine uranium tests performed periodicially since beginning work at the FMPC, the number of samples, timing, and reasons for testing (routine, exposure incident, follow-up, etc.) varied from person to person.

Furthermore, the other study limitations, discussed in the July 1987 report, relating to non-participation by retired employees, the effect of not accounting for deceased former employees, and the possibility that similar urine uranium levels in different persons may reflect a different pattern of kidney exposure because of differences in solubility of the various uranium compounds.

The urine uranium concentrations found during our survey suggested that current uranium exposures are within currently acceptable limits for occupationally exposed persons. The company data, however, suggest that exposures were higher in the past, although most study participants had cumulative urine uranium levels reflecting long-term exposures lower than the action level of 15 micrograms per liter recommended by the U.S. Nuclear Regulatory Commission (Regulatory Guide 8.22 -- Bioassay at Uranium Mills, issued in 1978).

In the July 1987 report, there were some numerical errors in Table 5; these were in the lines for shortness of breath ≥ grade 3 and ≥ grade 4. A corrected version of Table 5 is enclosed. The corrections do not affect any of the conclusions or require any changes in the text of the report.

The results of the environmental evaluation at the FMPC will be reported in a future communication, which will be sent to all persons receiving this letter.

Sincerely yours,

Mitchell Singal

Mitchell Singal, M.D., M.P.H.
Acting Chief
Medical Section
Hazard Evaluations and Technical
Assistance Branch
Division of Surveillance, Hazard
Evaluations, and Field Studies

Enclosures 2

TABLE A

Correlations between Summary Estimates[1] of Cumulative Uranium Exposure and Selected Renal Tests Results[2]

FEED MATERIALS PRODUCTION CENTER
FERNALD, OHIO
HETA 83-144
SEPTEMBER 16-27, 1985

| Renal test | Number of Participants | Estimate of Exposure: Sum of Annual Medians r* | Sum of Annual Medians p | Sum of Annual Maximums r | Sum of Annual Maximums p |
|---|---|---|---|---|---|
| Beta-2-microglobulin | 119 | 0.27 | 0.10 | 0.15 | 0.098 |
| Retinol binding protein | 121 | 0.04 | 0.70 | 0.07 | 0.47 |
| N-acetyl glucosaminidase | 120 | 0.01 | 0.88 | 0.11 | 0.25 |
| Albumin | 121 | -0.05 | 0.55 | 0.02 | 0.84 |

1 - See text.
2 - Creatinine-standardized urine concentrations.
* - Pearson's correlation coefficient.

TABLE 5

Health Parameters and Self-reported Uranium Exposure Incidents

FEED MATERIALS PRODUCTION CENTER
FERNALD, OHIO
HETA 83-144
SEPTEMBER 16-27, 1985

| Condition[1] | >1 Incident | 0 Incidents | Relative risk | 95% Confidence Interval | >20 Incidents | <20 Incidents | Relative risk | 95% Confidence Interval |
|---|---|---|---|---|---|---|---|---|
| Chronic cough | 9/78 (12)[2] | 4/63 (6) | 1.82 | 0.60 - 5.51 | 4/38 (11) | 9/103 (9) | 1.20 | 0.39 - 3.71 |
| Chronic bronchitis | 9/78 (12) | 1/63 (2) | 7.27 | 1.32 - 38.99 | 5/38 (13) | 5/103 (5) | 2.71 | 0.86 - 8.57 |
| Shortness of breath | | | | | | | | |
| ≥ grade 1 | 27/78 (35) | 17/62 (27) | 1.26 | 0.76 - 2.09 | 18/38 (47) | 26/102 (25) | 1.86 | 1.14 - 3.04 |
| ≥ grade 2 | 13/77 (17) | 4/62 (6) | 2.62 | 0.95 - 7.22 | 8/37 (21) | 9/102 (9) | 2.45 | 0.99 - 5.83 |
| ≥ grade 3 | 9/77 (12) | 1/62 (2) | 7.25 | 1.32 - 39.9 | 6/37 (16) | 4/102 (4) | 4.14 | 1.34 - 12.8 |
| ≥ grade 4 | 8/77 (10) | 1/62 (2) | 6.44 | 1.12 - 37.2 | 6/37 (16) | 3/102 (3) | 5.51 | 1.61 - 18.2 |
| Pulmonary function pattern | | | | | | | | |
| Restrictive[3] | 9/61 (15) | 5/49 (10) | 1.45 | 0.52 - 4.01 | 4/29 (14) | 10/81 (12) | 1.12 | 0.38 - 3.31 |
| Obstructive[3] | 13/61 (21) | 10/49 (20) | 1.04 | 0.50 - 2.18 | 5/29 (17) | 18/81 (22) | 0.78 | 0.32 - 1.88 |
| X-ray abnormalities | | | | | | | | |
| Pleural thickening | 4/70 (6) | 6/59 (10) | 0.56 | 0.17 - 1.87 | 2/34 (6) | 8/95 (8) | 0.70 | 0.16 - 3.09 |
| Bilateral pleural thickening | 2/70 (3) | 4/59 (7) | 0.42 | 0.08 - 2.12 | 1/34 (3) | 5/95 (5) | 0.56 | 0.07 - 4.45 |
| Selected Renal test abnormalities[4] | | | | | | | | |
| Serum | | | | | | | | |
| Beta-2-microglobulin | 2/69 (3) | 1/55 (2) | 1.59 | 0.15 - 16.86 | 2/34 (6) | 1/90 (1) | 5.29 | 0.63 - 44.4 |
| Retinol binding protein | 18/69 (26) | 11/55 (20) | 1.30 | 0.68 - 2.52 | 11/34 (32) | 18/90 (20) | 1.62 | 0.84 - 3.11 |
| Urine | | | | | | | | |
| Beta-2-microglobulin | 7/66 (11) | 10/57 (18) | 0.60 | 0.25 - 1.47 | 3/31 (10) | 14/92 (15) | 0.64 | 0.20 - 2.01 |
| Retinol binding protein | 4/67 (6) | 9/58 (16) | 0.38 | 0.13 - 1.13 | 3/33 (9) | 10/92 (11) | 0.84 | 0.25 - 2.84 |
| Alanine aminopeptidase | 8/61 (13) | 10/51 (20) | 0.67 | 0.29 - 1.57 | 6/30 (20) | 12/82 (15) | 1.37 | 0.56 - 3.36 |

1 - See text for definitions.
2 - Number with condition/number in category and (percent).
3 - Includes mixed restrictive/obstructive pattern.
4 - Only concentrations above the reference ranges (see Table 1) are considered abnormal for the purpose of these analyses.

Appendix C

# CHRONOLOGY OF MAJOR EVENTS
# PLUTONIUM OUT-OF SPEC (POOS) PROCESSING
(Information Provided By WMCO - [SIC])

| | |
|---|---|
| 3/85 | 1. Refinery U03 production suspended due to concerns about PU levels in the production stream. |
| 3/85-9/85 | 2. Joint DOE Task Force on Uranium Recycle Materials Processing formed and evaluated transuranic standards. |
| 9/85 | 3. Report from the Task Force issued. |
| 1/86 | 4. Transuranic spec formally changed by DOE. (166 MTU of Refinery produced 1.25% U03 now out-of-spec for PU; 89 MTU originally made on 8/84 - 9/84 plus 77 MTU produced 3/85). |
| 2/10/86 | 5. DOE approved WMCO planning to process POOS materials at FMPC. |
| 2/11-3/20 | 6. WMCO team began preparing procedure changes and training program for POOS processing in Plants 4 & 8. |
| 3/24-3/31 | 7. Conducted POOS training in Plants 4 & 8. |
| 4/04-4/09 | 8. Conducted POOS dry runs - Plants 4 & 8. |
| 4/23/86 | 9. Final WMCO Readiness Review Report. |
| 4/25/86 | 10. Site DOE review comments addressed. |
| 5/07/86 | 11. Began team planning and preparations for Plant 5 POOS processing. |
| 6/12/86 | 12. First DOE-ORO readiness review comments released. |
| 6/20/86 | 13. DOE-ORO readiness review team on-site inspection. |
| 7/03/86 | 14. WMCO responsed to on-site inspection findings and issued definition of successful campaign criteria. |
| 7/31/86 | 15. Internal WMCO readiness review of Plant 5 process conducted. |
| 8/11/86 | 16. DOE letter defining criteria required to start-up POOS operations in Plants 4 & 8 issued. |
| 8/01-10/15 | 17. WMCO actions to remove surface contamination in Plant 4 and meet maintenance requirements including all PMP work for FY-86. |

Appendix C (cont)

POOS CHRONOLOGY - CONTINUED

| | | |
|---|---|---|
| 8/18/86 | 18. | POOS refresher training conducted in Plant 8 to enable start-up for processing. |
| 8/20-8/21 | 19. | DOE walk-through and final approval to start Plant 8 POOS demonstration run (prior to planned Plant 4 work). |
| 8/25-10/12 | 20. | Plant 8 processing of 75,000 gallons of refinery raffinates. (Filter cakes in-spec; later dried for shipment to NTS). |
| 10/20-10/30 | 21. | Plant 4 POOS refresher training. |
| 10/20/86 | 22. | WMCO response to EPA concerns on Plant 4 POOS processing. |
| 11/03/86 | 23. | Refinery resumed normal operations after Plant 8 processing. |
| 11/05/86 | 24. | Formal DOE permission received to start Plant 4 operations. |
| 11/10/86 | 25. | POOS operations started in Plant 4. |
| 11/11/86 | 26. | POOS spill of U03 from Bank 9; [Plant 4] resulting Class B incident investigation. |
| 12/10/86 | 27. | WMCO recommended discontinued POOS processing in Plant 4 - material to be blended and recovered through Refinery at a later date to be defined. |
| 12/23/86 | 28. | WMCO responded to Class B investigation. |
| 2/10/87 | 29. | Three phase WMCO plan issued to return Plant 4 to non-POOS operations. |
| 3/26/87 | 30. | Letter to DOE on action plan to begin Refinery processing of POOS U03 starting 8/87. |
| 5/27/87 | 31. | DOE permission granted to restart Plant 4 and return area to non-POOS operations. |
| 6/3-6/10 | 32. | POOS refresher training; review of S.O.P's for POOS as well as normal operations. |
| 6/11-6/18/87 | 33. | Phase I operations. |

## POOS CHRONOLOGY - CONTINUED

| | | |
|---|---|---|
| 6/22-8/11/87 | 34. | Phase II operations. Bank 7 returned to non-POOS operating condition. Five MTU of POOS UF4 was blended off to non-POOS levels for use in Plant 5. A total of 161 MTU of POOS U03 now remains in inventory, properly stored/idenfied in Bldg. 64 and on the Plant 7 pad. |
| 9/11/87 | 35. | Letter to DOE recommending delayed POOS processing in the Refinery. |
| 2/03/88 | 36. | Multiple Discipline Appraisal provided by DOE for Plant 4 operations since POOS spill. |
| 4/88 | 37. | Phase III operations to return Bank 9 to non-POOS Operations are tentatively scheduled for: |
| 6/29-8/29/88 | | Phase III actual dates (Bank 9) |

Original File Copy

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Materials Company
of Ohio

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WMCO:OSH(IH):88:035

April 7, 1988

[redacted]
Site Manager
U. S. Department of Energy
P. O. Box 398705
Cincinnati, Ohio 45239

SUBJECT: **NATIONAL INSTITUTE FOR OCCUPATIONAL SAFETY AND HEALTH (NIOSH) PRELIMINARY REPORT**

Reference: (1) Letter, James M. Boiano and C. Eugene Moss to [redacted], dated March 7, 1988

(2) Letter, [redacted] to President, Westinghouse Materials Company of Ohio, "National Institute of Occupational Safety and Health (NIOSH) Preliminary Report", dated March 15, 1988

Dear [redacted]

The preliminary report (reference 1) of the environmental and radiologic evaluation conducted by the National Institute of Occupational Safety and Health (NIOSH) at the FMPC on December 1-3, 1987 contained nine (9) recommendations. WMCO has begun to implement corrective measures and, in reply to your request (reference 2), this letter provides a summary of actions taken and/or planned for each recommendation.

**NIOSH RECOMMENDATION #1:**

"1. The entire facility requires major attention towards cleaning the contamination that has been present for many years. Obviously those levels of contamination, both removable and non-removable, which exceed applicable DOE and/or WMCO limits require immediate attention. In addition, issues such as the repeated use of rags, cloths, and brushes visibly contaminated with uranium-bearing material in areas of Plant 4 should be made part of the contamination control policy. We believe this contamination issue requires

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administration attention and enforcement aspects mainly from DOE."

WMCO has submitted a plan of contamination control to DOE for review. This plan provides for operation of the FMPC under a three zone concept of contamination control. Zone 1 consists of clean areas such as the Cafeteria where no production area clothing is permitted. Zone 2 consists of transition areas in the restricted access area. Production area clothing or personal clothing with protective smocks and shoe covers are presently required. When contamination levels within defined limits for Zone 2 have been maintained on an on-going basis, requirements for protective smocks over personal clothes and shoe covers will be discontinued. Zone 3 designation is reserved for contaminated areas where controls and supplemental anti-contamination clothing is required. Personal clothing is not permitted in this area.

Contamination sources are isolated by Zone 3 barriers. Tracking of contamination from these areas will be effectively eliminated by zone controls and routine cleaning will be more effective in facility decontamination. An implementation task force has been established for the contamination control plan. It is composed of Production Operations, Maintenance and Health Physics management. The task force plan is to identify Zone 3 areas by April 9 and to initiate installation of zone barriers by April 29, 1988.

Another activity which is directed to facility decontamination is the implementation of a job classification, High Level Cleaner. Personnel in this classification provide decontamination and cleaning of elevated building structures. Also, a contract to characterize "abandoned-in-place" equipment as the basis for scheduling its removal is being initiated. Concerns expressed about the use of contaminated materials in Plant 4 are part of the expanding site contamination control effort. Daily radiation surveillance activities and routine radiological facility inspections will be the prime means of implementing corrective actions.

<u>NIOSH RECOMMENDATION #2:</u>

"2. At present it is our understanding that the only on-site DOE personnel are contract monitors with oversight responsibilities. While this oversight activity is crucially important for overall plant operations, it may not be the proper administrative mechanism to ensure resolution of occupational safety concerns, particularly contamination. One way to ensure decontamination is to assign an experienced on-site

DOE health physicist/industrial hygienist to the FMPC facility. This individual must have the appropriate administrative authority to complete this task."

While DOE may choose to appoint an individual with oversight responsibility for contamination concerns, WMCO has and is continuing to make significant progress in contamination control. ORO has recently provided an OR-wide contamination control policy and efforts to control contamination are closely coupled to development of a corresponding work ethic, to engineering upgrading of facilities and to disposal of abandoned equipment. This effort is ongoing and has a high priority at FMPC.

NIOSH RECOMMENDATION #3

"3. The lack of WMCO attention towards following the dictates of its own radiation control manual was clearly illustrated when we visited the counting room to witness how samples were counted and handled by the Health and Safety Division trained radiation personnel. Technicians were observed smoking, drinking and eating while handling radiological samples. When the NIOSH investigator asked them of this practice he was told that the smoke gets worse when more people are in the counting room. In fact, a fan had to be installed to disperse the smoke produced from the smokers. Surely such a practice needs to stop immediately. The impact of such procedures on overall plant morale and health/safety issues is, in our opinion, very negative and does the entire operation a disservice."

The counting room has been properly posted as a "Radioactive Materials Area, Eating, Smoking, Drinking are not permitted." This has eliminated the questionable practices raised in the NIOSH report and completes the recommended corrective action of item #3.

NIOSH RECOMMENDATION #4:

"4. Given the fact that many surfaces in the Plants where we made measurements are radiologically contaminated, it is imperative that workers store their respirators in a clean location when not in use. This practice should prevent inadvertent ingestion of radiation contaminated materials."

The following actions have been taken by WMCO prior to or since the NIOSH audit: an increased frequency of respirator usage and storage audits was initiated in the production areas which specifically includes making sure that respirators are stored in a clean location when not in use; a new audit form was introduced which provides immediate feedback to supervisors of respirator findings and discrepancies; guidelines for respirator storage and usage plus a summary of respirator audit findings were sent to all supervisors participating in the Respiratory Protection Program; employees are given training on proper respirator practices during their periodic respiratory protection training classes.

In addition, WMCO plans to begin a special training course for FMPC supervisors dealing with proper respirator practices. There will be continued emphasis on compliance with existing requirements and on proper respirator practices through training, routine periodic audits and informative correspondence.

NIOSH RECOMMENDATION #5:

"5. Given the fact that the chip pickling tank operator was exposed to $NO_2$ at a concentration approximating the NIOSH REL, additional air monitoring should be conducted by WMCO when the process is operating to better define this worker's daily average exposure. If resampling shows that $NO_2$ exposures are no different than what we had measured improvements in the local and/or general ventilation may be necessary to reduce exposure."

Additional air sampling was conducted by WMCO from March 15-25, 1988 after operation of the ventilation system was verified. Sampling was performed for nitrogen dioxide, nitric oxide and nitric acid during days when the process was actually operating as well as on days when the operation was not running. These samples are being submitted for analysis to determine worker exposure and general area contaminant concentrations.

Planned actions entail a review of the air sampling results and comparison with limits, and based on this review a determination will be made as to whether additional ventilation will be required to reduce worker exposure.

NIOSH RECOMMENDATION #6:

"6. Although the drum sampling operation in Plant 1 is adequately ventilated, workers expressed concern that the drum lidding operation (currently not ventilated) can also generate airborne dust, especially when drums containing dry (waste) material are being lidded. Airborne dust from the drums can be controlled by utilizing the existing LEV system servicing the drum sampling station."

Prior to the NIOSH visit, an engineering review of the Plant 1 drum lidding operation was performed by WMCO for the purpose of providing ventilation to this operation. The design of this improvement is now undergoing plant review prior to final design.

Planned actions include a review and evaluation of currently available air sampling data for the Plant 1 drum lidding operation, and performance of additional air sampling as needed to determine whether interim control measures will be needed prior to extending ventilation to the lidding operation.

NIOSH RECOMMENDATION #7:

"7. Air capture at the opening of the ventilated enclosure of the #1 green salt drumming station in Plant 4 was compromised by air currents from an overhead supply air duct whose diffuser grill was directed toward the pack-out station. Repositioning of the diffuser will correct this problem."

The work station was investigated by WMCO and maintenance will be performed to modify the overhead air source so that the drumming station ventilation is not compromised. After the modification the efficacy of the repairs will be evaluated by the Operational Safety & Health Department.

NIOSH RECOMMENDATION #8:

"8. The reactor pot access doors to the capping stations in Plant 5 were kept open during the capping operation when magnesium fluoride was added to "top off" the pots. Because the LEV systems for this operation were designed to provide maximum capture or suction when the doors are closed, we recommend that workers always close the access doors when capping the pots to ensure maximum removal of any airborne particulate."

WMCO workers have been reinstructed to comply with "Keep Closed" signs posted on the pot access doors to the capping stations in Plant 5.

Planned actions include continued emphasis on compliance by Plant 5 supervision, and inclusion of this item in periodic walkthrough surveys by Operational Safety and Health Department personnel.

NIOSH RECOMMENDATION #9:

"9. The downdraft hood servicing one of the lathes in the graphite machining department (Plant 5) was partially obstructed with graphite chips. After removing the chips, full suction was restored. Our observations demonstrate the need to increase the air velocity in the exhaust duct to help prevent settling of graphite particulates in the hood."

The operation was reviewed by WMCO and maintenance will be performed to increase the air velocity in the exhaust duct by installing dampers to enable closing graphite equipment ductwork not in use and thus provide increased exhaust ventilation for the equipment in operation.

Very truly yours,

[redacted]

[redacted] Manager
Operations Safety & Health

CNS:em

cc: [redacted]

The sampling method for particulate and gaseous fluorides (NIOSH Method 7902) requires the use of two filter cassettes in line with one another. The first cassette contains a 37 mm, 0.8 um cellulose membrane filter seated on an untreated back-up pad for collection of prticulate fluorides. The second cassette contains a sodium carbonate-treated back-up pad for collection of gaseous fluorides. Subsequent to sample collection the NIOSH analytical laboratory informed us that the untreated back-up pad may collect as much or more of the gaseous fluorides than the treated pad. Accordingly, we arranged for our contract analytical laboratory to analyze both back-up pads. Unfortunately, only the treated pad was analyzed. As a result, all levels reported for gaseous fluorides may be low to some extent. Nevertheless, it should be noted that this problem did not seriously impact on our study since it is doubtful whether the total fluoride levels in these samples would have exceeded the evaluation criteria given that the operations evaluated during our survey would not be expected to liberate appreciable amounts of gaseous fluorides. NIOSH Method 7902 is currently being reevaluated with respect to the gaseous fluoride filter absorption problem. Nonetheless, this method can still be used for the determination of total fluorides provided that all filter media are analyzed.

**Department of Energy**
Oak Ridge Operations
P. O. Box E
Oak Ridge, Tennessee 37831

JUL 15 1988

DOE-1157-88

Mr. James M. Boiano, M.S., CIH
Department of Health & Human Services
National Institute for Occupational
Safety and Health
Robert A. Taft Laboratories
4676 Columbia Parkway
Cincinnati, Ohio 45226-1998

Dear Mr. Boiano:

**SUBJECT: NATIONAL INSTITUTE FOR OCCUPATIONAL SAFETY AND HEALTH (NIOSH) PRELIMINARY REPORT**

Reference: Letter, HETA 83-144, J. M. Boiano and C. E. Moss to [redacted], dated March 7, 1988.

Although this report is preliminary and not final we have taken action to mitigate your concerns. Attached is our response to your preliminary report concerns.

Plans are that, DOE will assign an independent environmental and health person to the Feed Materials Production Center within the next Fiscal Year. This should satisfy recommendation number 2.

If there are any questions concerning this, please call me or [redacted] at [redacted].

Sincerely,

DP-84:[redacted]

Attachment: As stated