PROCESSING OF URANYL NITRATE HEXAHYDRATE (UNH) AT DOE'S FERNALD SITE - SUCCESS & PITFALLS

BY
DONALD W. LUKEN*
DAVE J. BRETTSCHEINER*
ROBERT P. HECK II*
CHRISTOPHER A. WHITE (DOE-FERNALD)

FERMCO*
Fernald Environmental Management Project
P.O. Box 538704
Cincinnati, Ohio 45253-8704

For Presentation at the
WM '96 Conference - Tucson, AZ
February 26, 1996

DISCLAIMER

This report was prepared as an account of work sponsored by an agency of the United States Government. Neither the United States Government nor any agency thereof, nor any of their employees, makes any warranty, express or implied, or assumes any legal liability or responsibility for the accuracy, completeness, or usefulness of any information, apparatus, product, or process disclosed, or represents that its use would not infringe privately owned rights. Reference herein to any specific commercial product, process, or service by trade name, trademark, manufacturer, or otherwise does not necessarily constitute or imply its endorsement, recommendation, or favoring by the United States Government or any agency thereof. The views and opinions of authors expressed herein do not necessarily state or reflect those of the United States Government or any agency thereof.

*Fernald Environmental Restoration Management Corporation with the U. S. Department of Energy under Contract No. DE-AC24-920R21972

DISTRIBUTION OF THIS DOCUMENT IS UNLIMITED...
DISPOSITION OF URANYL NITRATE HEXAHYDRATE (UNH) AT THE DEPARTMENT OF ENERGY - FERNALD SITE

THE SUCCESSES AND PITFALLS

AUTHORS: FERMCO, Donald W. Luken, Dave J. Brettschneider, Robert P. Heck; DOE, Christopher A. White

BACKGROUND
After 36 years of operation, uranium production at the Department of Energy (DOE) Fernald Environmental Management Project (FEMP) was halted in 1989. Uranyl nitrate hexahydrate (UNH) had been produced during the uranium refining. The definition of UNH is nitric acid with a pH < 2 and uranium concentrations greater than 10 grams uranium per liter. When production operations were shut down, over 200,000 gallons of UNH remained in stainless steel tanks in various locations within the Fernald Plant 2/3 complex.

In June 1991, DOE determined the UNH to be a mixed hazardous waste under the Resource Conservation and Recovery Act (RCRA). The UNH was hazardous due to its corrosive properties, pH < 2, (40 Code of Federal Regulations [CFR] 261.22) and its toxicity characteristics (40 CFR 261.24) because of the presence of heavy metals (barium, chromium, lead, and mercury).

The UNH Neutralization Project consisted of the processing of UNH stored in nineteen stainless steel tanks located in various areas within the Fernald Plant 2/3 complex. The UNH uranium content in these tanks ranged from 13 to 341 grams of uranium per liter (g/l). The quantity of uranium amounted to a nominal 100 metric tons. Six of the nineteen tanks had an U235 enrichment of 1% or greater. A Criticality Safety Analysis indicated that for the concentrations involved there was no potential for criticality with the enriched materials during any of the conditions to be encountered, including processing, containerization and shipment of solids, or any credible accident scenario. The UNH material had a free acid content of up to 4.7 Normality. Table 1 summarizes the uranium concentration for each tank.

RCRA treatment required that the neutralized UNH have a pH > 2 and concentrations of RCRA metals (measured by the Toxicity Characteristic Leaching Procedure [TCLP]) at the following levels: barium < 100 ppm, chromium < 5 ppm, lead < 5 ppm, and mercury < 0.2 ppm. Table 1 also summarizes the RCRA characteristics for the contents of each tank.

RCRA closure requirements for the UNH tanks required final rinse samples to have a pH > 2 and concentrations of RCRA metals, as follows: barium < 1 ppm, chromium < 1 ppm, lead < 0.6 ppm, and mercury < 0.03 ppm.

In 1991, leaks were discovered in the valves, flanges, and other fittings of the UNH storage tanks. Processing the UNH then became a high priority and Comprehensive Environmental Response, Compensation, and Liability Act (CERCLA) Removal Action No. 20, Stabilization of UNH Inventories, was initiated. Clean closure of the tanks, a RCRA hazardous waste management unit (HWMU), was integrated with this removal action. The UNH was processed according to an Ohio Environmental Protection Agency (OEPA) and U.S. EPA-approved work plan. The
completion of this project marked the end of the first large-scale closure of a
RCRA HWMU integrated into the CERCLA process and prior to the Record of Decision
(ROD).

In 1992, approximately 20,000 gallons of UNH were processed using the existing
pumps, piping, tanks, and valves. On April 27–28, 1993, there was a UNH spill,
resulting in a Type B Investigation that ultimately led to the Department of
Energy (DOE) Office of the Assistant Secretary for Environmental Management
(EM-1) committing to the Defense Facility Nuclear Safety Board (DNFSB) to be the
startup authority. An Operational Readiness Review (ORR) would be required prior
to processing the UNH.

The new process design, based on having no leaks during operations, was performed
from December 1993 to April 1994 and included new dedicated piping, new valves,
and new progressive cavity pumps. In October 1994, after the new progressive
cavity pumps had leaked, they were replaced with double diaphragm pumps.
Construction of the process system started in May 1994 and was initially
completed in December 1994.

During December 1994 and January 1995, FERMCO, the site contractor, performed a
System Operability Test (SOT) to verify that all valves, pumps, instrumentation,
interlocks, and other equipment met operation requirements. Since numerous
problems were identified during the SOT (i.e., a cracked weld in a carbon steel
pipe and double diaphragm pumps), FERMCO performed a Design Review to resolve
these problems.

On December 27, 1994, the OEPA issued a Director’s Final Findings and Orders
(DF&O), which established a deadline for startup and completion of the UNH
Project. The DF&O specified that fines and penalties would be incurred if the
removal action was not started by January 17, 1995, and completed by September
25, 1995. Although the project startup date was missed because of the above
problems, through teamwork, dedication, effective problem solving, and improved
operational efficiency, the UNH Neutralization Project was completed August 30,
1995, one month before the mandated DF&O completion date.

CRITICAL PATH METHOD (CPM) SCHEDULE
A CPM schedule was established on February 10, 1995, to track all activities
required to complete the UNH Neutralization Project ORR and to complete
operations. On May 17, the project was ready for FERMCO’s ORR to begin.
Process startup would be granted by EM-1 after successful completion of FERMCO’s
ORR, DOE’s ORR, and correction of all prestart findings. FERMCO’s readiness
allowed the ORR cycle to be completed on June 15, with EM-1 authorizing startup
of operations, more than a month ahead of the scheduled date of July 20. FERMCO
worked diligently to improve operational efficiency and operations were completed
on August 30, 1995, one month ahead of the DF&O deadline of September 25, 1995,
and more than seven months ahead of the scheduled completion date of April 6,
1996.
UNH PROCESSING
The old UNH piping network was not used because it was so intricate that it was difficult to determine where UNH would exit the system. To improve process control, reduce the possibility of leaks, and removed the possibility of sending UNH to an unintended destination, a new stainless steel transfer piping system was installed to transfer UNH from individual storage tanks to the dilution/neutralization tanks. Carbon steel piping was used to transfer the neutralized liquids to the EIMCO™ filter, which removed the precipitated uranium from the neutralized liquids. All flange connections on piping, valves, and pumps were located within either permanent or temporary secondary containment. An extensive maintenance repair program was performed on all reused equipment and the operational readiness of all equipment was verified by a SOT.

The UNH material was transferred from the storage tanks to an agitated processing tank and diluted with water, if necessary, to adjust the acid normality to < 1 and the uranium content to < 100 g/l. Magnesium hydroxide was then pumped into the process tank to neutralize the nitric acid and to precipitate out the uranium and heavy metals. After precipitation was completed, a uranium concentration < 48 ppm and a pH > 6 was verified before the neutralized UNH, magnesium diurnate (MDU), was pumped to the Plant 8 Wastewater Treatment System (WWTS) for filtration. In Plant 8, the MDU was filtered through an EIMCO™ filter, a rotary drum vacuum filter. The resulting filter cake was placed into 55-gallon drums and sampled to verify that the material passed TCLP and met the Waste Acceptance Criteria (WAC) for disposal at the Nevada Test Site (NTS). The filtrate contained nitrates, which were removed by the FEMP biodegradation system and discharged in accordance with the FEMP National Pollution Discharge Elimination System (NPDES) permit.

IN-SITU NEUTRALIZATION
A Readiness Assessment (RA), performed in accordance with DOE Order 5480.31, verified that the UNH Neutralization Project was ready to begin in-situ neutralization with Magnesium Oxide (MgO) on March 24, 1995. This date met the DF&O startup requirement. Screening criteria were developed to select UNH tanks that could be neutralized in place, without transferring UNH to a processing tank. The UNH had to have a uranium concentration < 100 g/l, a Normality < 3, and the selected tank had to have an operational agitator. The in-situ neutralization process involved dumping a few bags of MgO each day and agitating the tanks for several hours each day until neutralization and precipitation were complete.

ENGINEERING PROBLEMS - CORRECTIVE ACTIONS
From January 1995 through March 1995, the UNH Neutralization Project focused on the following activities:

- Ultrasonic Testing (UT) of the stainless steel pipe welds and internal visual inspection of the welds for the carbon steel pipe, to verify that the piping was acceptable to transfer UNH from storage tanks to the processing tank and to transfer the neutralized UNH from Plant 2/3 to the Plant 8 WWTS for filtration;
Replacing the double diaphragm pumps with the originally designed progressive cavity pumps, which had been replaced by the manufacturer; and,

Completing repairs and calibrations to equipment and instrumentation that had not worked properly during the SOT. Quality Assurance (QA) played a major role during this work and verified that corrective actions were properly completed.

**PRE-OPERATIONAL READINESS REVIEW ACTIVITIES**

On March 31, 1995, after another successful RA was completed, the UNH was transferred from Tank D1-1 to Tank D1-2 to ensure that a catastrophic leak did not develop in the deteriorated piping on the bottom of the tank. The successful completion of this RA, when combined with the successful completion of the RA for in-situ neutralization the previous week, helped prepare the UNH Neutralization Project for the FERMCO and DOE ORRs.

From February 1995 to May 1995, FERMCO completed several activities that were critical for project readiness.

- Safety Analysis Report and Technical Safety Requirements were approved;
- Project Specific Health and Safety Plan was revised;
- Conduct of Operations Applicability Matrix was approved;
- Identification of Standards/Requirement Identification Documents (S/RIDs) and a corrective action schedule for items that were not in compliance was approved;
- Numerous self assessments were completed and corrective actions implemented;
- Operator training was completed;
- SOTS were successfully completed;
- Practice runs using water for transfer operations were completed;
- A training matrix was developed showing all required operator training had been completed; and,
- Operational procedures were completed and approved.

An internal FERMCO assessment team was formed to review all aspects of the UNH Neutralization project to ensure that the process was ready to operate and would successfully complete the ORR cycle. When problems were identified, the assessment team notified the project team and corrective actions were implemented. The FERMCO ORR and DOE ORR were successfully completed and the EM-1 authorized startup within a 30-day cycle.

**OPERATIONAL READINESS REVIEW (ORR) CYCLE**

ORRs were performed by FERMCO and DOE prior to startup of the UNH Neutralization Project. Key documents were the FERMCO ORR Plan of Action and the DOE ORR Plan of Action. Both documents were approved by EM-1 in November 1994.

The FERMCO ORR Implementation Plan was approved by the FERMCO ORR Team Leader in May 1995. The DOE ORR Implementation Plan was approved by the DOE ORR Team Leader in May 1995.
FERMCO declared that they were Ready to Operate on May 17 and the FERMCO ORR began the same day. The FERMCO ORR was completed on May 24 and the Final Report was issued on May 26. The FERMCO ORR identified eleven prestart findings that had to be closed prior to startup and FERMCO provided a schedule showing that all prestart findings would be closed by June 7. EM-1 authorized the DOE ORR to begin June 5.

The DOE ORR was completed on June 9. During the DOE ORR, three prestart findings were identified. All of the FERMCO ORR prestart findings and all of the DOE ORR prestart findings were satisfactorily closed. The DOE ORR Final Report was completed on June 14 and startup was authorized by EM-1 on June 15, just 30 days after the FERMCO ORR had started.

The DOE ORR team noted several areas of excellence, including:

- Improvements in housekeeping,
- Improvements in workplace and access discipline,
- Excellent Engineering support,
- Operator knowledge/skills/level of training,
- Above average implementation of Conduct of Operations principles/practices,
- Can-do attitude of UNH Project Team,
- Radiological controls,
- Operational control of evolutions, and
- Capability to respond to unanticipated anomalies.

OPERATIONAL PROCESSING SCHEDULE IMPROVEMENTS
The original work plan included 180-days of operation to complete transfer, neutralization, and filtration operations. This schedule included 27 batches for transfer, neutralization, and filtration, processing each tank individually, and relocating pumps and temporary piping. FERMCO created a team to determine if a more efficient operation could be developed to reduce the operating schedule.

Existing plans were to remove the UNH from the storage tanks using top discharge. By implementing a carefully planned maintenance program, existing piping downstream of the nearest tank bottom outlet valve was removed and a second new backup valve installed to provide a redundant safe configuration. This simplified pumping and priming functions and eliminated the need to install recycle piping to help agitate the tanks. Also, more then one tank was hooked up at a time and different tanks were blended together. Blending the material in the tanks improved production and resulted in reduced quantities of dilution water. Therefore, it was possible to neutralize, precipitate, and filter the material much more efficiently than previously anticipated. Blending UNH from different tanks reduced the quantity of MDU with a U235 enrichment greater than 1%, which reduced the administrative requirements for storage and shipment.

To speed up temporary piping hookups, all fittings, hoses, and spool pieces were inventoried and marked. To reduce installation time, sketches of each installation were made, noting the numbered pieces required to make up a system. This enabled maintenance and QA to plan their work so modifications to the piping system were done quickly and properly.
To increase processing efficiency, a second dilution/neutralization/precipitation tank was prepared. This action not only reduced neutralization/precipitation time, but also provided needed flexibility for processing the UNH during operations.

Another improvement to operations was the coordination with the site laboratory to process samples from the UNH Neutralization Project on a priority basis. A laboratory coordinator was named to the project team and a strategy was developed to provide communication and interface between field and laboratory personnel. The use of appropriate laboratory procedures and effective communication between field and laboratory personnel provided fast turnaround analysis throughout the project. The pH and uranium content were critical to the project, because those parameters determined when neutralization and precipitation were complete and that the MDU could be pumped to the Plant 8 WWTS for filtration. Typically, the lab was able to provide responses on pH and uranium content within a few hours after receiving the samples. After rinsing out the UNH storage tanks, data was required to ensure that the UNH tanks met RCRA closure requirements prior to pump disconnection and movement. During operations it was found that if the pH of the rinse water was more than 4.5 to 5, the tank was clean.

Improving the system piping configuration, effective scheduling and schedule management, and the ability to receive laboratory data in a real-time mode shortened the processing schedule by 7 months and allowed the project to be completed almost a month before the DF&O completion deadline. These modifications also assured worker safety and reduced the potential of releases to the environment.

FIELD CHANGES TO THE CHEMICAL PROCESS

Full-scale operational problems related to system chemistry required that project adjustments be made. Scaled-up batch characteristics did not reflect bench-scale testing. The pH adjustment problems were partially attributed to the heterogeneous nature of the UNH stored in the different tanks. During past processing practices, production grade UNH had been accumulated, as well as UNH from waste and recycle sumps. These variations in material caused each batch to process differently.

Accurate analytical results from process and rinse samples became even more important to make operational adjustments and permit maintenance personnel to move piping and pumps from the various locations in and outside of the Plant 2/3 complex. The following section describes the problems encountered and how they were overcome.

UNH materials were sampled and analyzed for acid normality, uranium content, enrichment, and RCRA metals. Analytical results (Table 1) showed a variety of UNH solutions of varying composition. Acid normality ranged from 0.19 N to 4.6 N, uranium concentration ranged from 20 g/l to 341 g/l, U235 enrichment ranged from 0.87% to 1.29% U235.
Extensive bench-scale testing was preformed on the UNH liquids. Testing goals were to process UNH to a filterable material with the required pH. Uranium and RCRA metal concentrations of filtrate were required to meet limits prior to discharge into the FEMP WWTS for nitrate removal.

In the first full-scale batches of material processed, the proper pH value, as determined by bench-scale testing, was not obtained. Field changes to the work plan were made to correct the problem by diluting the batches and solubilizing more magnesium hydroxide for quicker pH adjustment. Additional samples were taken to track progress of the batches in meeting the desired pH and uranium limits.

As mentioned before, analytical data was obtained from the laboratory in a real-time manner to allow the field supervisor to make decisions about the next step in processing each UNH batch. In addition to RCRA metals, the laboratory was able to report additional metal results, produced from an Inductively Coupled Plasma (ICP) instrument. Since the ICP can simultaneously analyze up to twenty metals, results for magnesium, calcium, sodium, and other metals, which may have affected the processing, were also reported to determine which metals were affecting the dissolution rate of the magnesium hydroxide and the final pH.

Processing of the UNH materials in the first three weeks was extremely slow due to the time required to reach the initial level of 7 (a Technical Safety Requirement [TSR]). The immediate solution to this problem was to dilute process batches with water, which decreased the time required to reach the final pH, but produced more contaminated water that had to be stored for denitrification prior to discharge.

Another concern was the limited storage capacity for high nitrate filtrate. High nitrate filtrate was produced by the filtering operation in Plant 8. The filter cake went into 55-gallon drums. The high nitrate filtrate went into a storage tank. If the project had to continue diluting the UNH, as was required for the first few batches, there may not have been sufficient storage capacity on site for the high nitrate filtrate and the UNH Neutralization Project would have been stopped.

The UNH Neutralization Project operators recommended that lime be added to the batch to bring the pH up to the required level. After carefully reviewing the analytical data from each step of the processed batches, the project chemists concurred, and an Unreviewed Safety Question Determination (USQD) was prepared that allowed lime to be added after the Mg(OH) was added. Another USQD and TSR revision was prepared to lower the final pH from more than 7.0 to more than 6.0. The batch processing time was decreased and the amount of high nitrate water produced was minimized.
MOVING PUMPS ON PRELIMINARY DATA AND EFFECTIVE RINSE PROJECTIONS

To meet RCRA closure requirements, each emptied UNH tank was rinsed until the analytical data confirmed that the pH of the final rinse had a pH greater than 2 and less than 12.5 and the RCRA metals were below the OEPA Closure Guidance limits. In order to move equipment and rinse the tanks without delays, a strategy was developed employing field pH instruments, laboratory screening analysis, and project chemist predictions of analyte concentrations after rinsing to determine when closure requirements were achieved. A final rinse sample was submitted to the laboratory for analysis to verify that closure requirements were indeed met. The final rinse samples were analyzed by EPA methods to produce a data package for validation to support closure. Typical laboratory turnaround time was 31 days.

Table 1 shows the RCRA metal concentration in the UNH tanks. Table 2 shows the minimum dilution of the heel remaining in each tank for each RCRA analyte to achieve clean closure. Dilution factors are shown for the limiting RCRA metal and acid normality. By analyzing the constituents that would require the most dilution, laboratory delays and work load were minimized. Sampling results were available in one hour or less and the decision to rerinse or move equipment was easily determined. When the validated rinse sample results were reviewed it was found that, as predicted, all tanks had meet the RCRA closure requirements.

CONCLUSIONS

UNH material was safely and successfully removed and processed within the deadline set by the OEPA's DF&O. All UNH tanks met OEPA RCRA closure requirements. The following factors led to this success.

1) The simplification of process transfer operations allowed rapid movement from one storage tank to the next. The reconfiguration of piping to allow bottom discharging eliminated much of the planned temporary piping systems.

2) Dedicating an individual to each key element of the project allowed attention to critical details. Appointing a laboratory coordinator to the process team assured sample delivery, communication between laboratory and field personal, and assured results could be used in a real-time mode.

3) Using analytical screening methods with the dilution of analyte charts allowed field supervisors to make decisions about the adequacy of rinse before receiving final validated laboratory data. This coordination and logic scheme allowed for the on-site laboratory to be used to assist in the real-time mode of operation and the project supervision in deciding quickly to repeat a process step or move equipment to the next process area. This technique ensured efficient use of work force and allowed rapid deployment of resources.

4) Continual process improvement by the entire UNH team ensured successful completion of the UNH project (i.e., in situ neutralization of some tanks was suggested by the chemical operators as a way to meet project deadlines).
5) Using process data to re-evaluate the final pH for each batch, and to support changes to the process, increased production rates, reduced process water requirements, and ensured the early completion of the project. The use of lime to adjust the final pH speeded the process and overcame a critical magnesium saturation problem.

Disclaimer

This paper was prepared as an account of work sponsored by an agency of the United States government. Reference herein to any specific commercial product, process, or service by trade name, trademark, manufacturer, or otherwise does not constitute or imply its endorsement, recommendation, or favoring by the United States government or any agency thereof. The views and opinions of authors expressed herein do not necessarily state or reflect those of the United States government, or any agency thereof or Fernald Environmental Restoration Management Corporation, its affiliates or its parent companies.
<table>
<thead>
<tr>
<th>Tank No.</th>
<th>Pb</th>
<th>Ba</th>
<th>Cr</th>
<th>Hg</th>
<th>Metals Over RCRA Limit, 95% Confidence</th>
<th>Analyte List for Tank Closure</th>
<th>Uranium g/l</th>
</tr>
</thead>
<tbody>
<tr>
<td>SE F2E-5</td>
<td>3.8</td>
<td>15</td>
<td>4.1</td>
<td>0.52</td>
<td>Pb, Cr, Hg</td>
<td>Pb, Ba, Cr, Hg</td>
<td>122</td>
</tr>
<tr>
<td>NE F2E-6</td>
<td>3.5</td>
<td>11.6</td>
<td>2.6</td>
<td>&lt;.01</td>
<td>Pb</td>
<td>Pb</td>
<td>202</td>
</tr>
<tr>
<td>SW F2E-8</td>
<td>1.1</td>
<td>7.8</td>
<td>1.8</td>
<td>0.43</td>
<td>Pb, Cr, Hg</td>
<td>Pb, Ba, Cr, Hg</td>
<td>57.3</td>
</tr>
<tr>
<td>D1-1</td>
<td>17.7</td>
<td>79</td>
<td>465</td>
<td>1.0</td>
<td>Pb, Ba, Cr, Hg</td>
<td>Pb, Ba, Cr, Hg</td>
<td>135</td>
</tr>
<tr>
<td>D1-10</td>
<td>24.1</td>
<td>99</td>
<td>1003</td>
<td>5.5</td>
<td>Pb, Ba, Cr, Hg</td>
<td>Pb, Ba, Cr, Hg</td>
<td>154</td>
</tr>
<tr>
<td>F1-1</td>
<td>84.6</td>
<td>412</td>
<td>344</td>
<td>2.8</td>
<td>Pb, Ba, Cr, Hg</td>
<td>Pb, Ba, Cr, Hg</td>
<td>48.4</td>
</tr>
<tr>
<td>F1-25</td>
<td>30.0</td>
<td>133</td>
<td>140</td>
<td>2.04</td>
<td>Pb, Ba, Cr, Hg</td>
<td>Pb, Ba, Cr, Hg</td>
<td>133</td>
</tr>
<tr>
<td>F1-2</td>
<td>18.7</td>
<td>51.8</td>
<td>290</td>
<td>0.51</td>
<td>Pb, Cr, Hg</td>
<td>Pb, Ba, Cr, Hg</td>
<td>85</td>
</tr>
<tr>
<td>F1-301</td>
<td>19.4</td>
<td>140</td>
<td>83.5</td>
<td>2.22</td>
<td>Pb, Ba, Cr, Hg</td>
<td>Pb, Cr, Hg</td>
<td>60.3</td>
</tr>
<tr>
<td>F1-302</td>
<td>4.7</td>
<td>28.4</td>
<td>26.4</td>
<td>0.34</td>
<td>Pb, Cr, Hg</td>
<td>Pb, Cr, Hg</td>
<td>13.2</td>
</tr>
<tr>
<td>F1-303</td>
<td>8.3</td>
<td>41.5</td>
<td>93.9</td>
<td>3.14</td>
<td>Pb, Cr, Hg</td>
<td>Pb, Ba, Cr, Hg</td>
<td>18.5</td>
</tr>
<tr>
<td>F1-308</td>
<td>11.4</td>
<td>81.6</td>
<td>249</td>
<td>1.98</td>
<td>Pb, Ba, Cr, Hg</td>
<td>Pb, Ba, Cr, Hg</td>
<td>30.3</td>
</tr>
<tr>
<td>F2-605</td>
<td>17.2</td>
<td>94.6</td>
<td>59.4</td>
<td>0.72</td>
<td>Pb, Ba, Cr, Hg</td>
<td>Pb, Ba, Cr, Hg</td>
<td>59.1</td>
</tr>
<tr>
<td>F2-606</td>
<td>15.7</td>
<td>96.8</td>
<td>49.4</td>
<td>0.71</td>
<td>Pb, Ba, Cr, Hg</td>
<td>Pb, Ba, Cr, Hg</td>
<td>55.4</td>
</tr>
<tr>
<td>F2-607</td>
<td>18.4</td>
<td>182</td>
<td>69.4</td>
<td>1.13</td>
<td>Pb, Ba, Cr, Hg</td>
<td>Pb, Ba, Cr, Hg</td>
<td>36.9</td>
</tr>
<tr>
<td>F2-608</td>
<td>18.2</td>
<td>151</td>
<td>147</td>
<td>1.01</td>
<td>Pb, Ba, Cr, Hg</td>
<td>Pb, Ba, Cr, Hg</td>
<td>68.0</td>
</tr>
<tr>
<td>F3E-220</td>
<td>3.5</td>
<td>&lt;2</td>
<td>10.6</td>
<td>0.24</td>
<td>Pb, Cr, Hg</td>
<td>Pb, Cr, Hg</td>
<td>20.0</td>
</tr>
<tr>
<td>F3E-223</td>
<td>&lt;.3</td>
<td>&lt;2</td>
<td>0.8</td>
<td>0.22</td>
<td>Hg</td>
<td></td>
<td>341</td>
</tr>
</tbody>
</table>