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TREATMENT AND DISPOSAL OF A MIXED F006 PLATING LINE SLUDGE AT THE SAVANNAH RIVER SITE (U)

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TREATMENT AND DISPOSAL OF A MIXED F006 PLATING LINE SLUDGE AT THE SAVANNAH RIVER SITE

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ABSTRACT. The Westinghouse Savannah River Company (WSRC), as the operating contractor for the Department of Energy (DOE) at the Savannah River Site (SRS) is implementing a program to treat and stabilize approximately 750,000 gallons of an F006 mixed (radioactive/hazardous) plating line wastewater sludge. The uranium contaminated sludge resulted from nickel plating of depleted uranium targets, which were subsequently irradiated to produce plutonium for the weapons program. With the end of the "cold war", no virgin plutonium weapons production is forecast, and only the current SRS inventory of stored mixed plating line waste must be treated and disposed. A Life Cycle Cost analysis was used by WSRC to determine that the most cost effective approach was to treat the waste by a hazardous waste management sub-contractor, in a one time campaign. The analysis indicated that ~\$40 million could be saved by this approach, vs. the original plan to construct a permanent SRS treatment facility. The sub-contractor will mobilize treatment equipment on site, treat, stabilize, and place the final wasteform in disposal containers. The stabilized waste will be disposed to on-site SRS disposal vaults. This new approach also required a re-negotiation of a federal facility compliance agreement between the DOE and the Environmental Protection Agency.

INTRODUCTION

The end of the Cold War has caused major changes in the entire DOE weapons complex. A direct result of the reduced need for weapons production has been a re-evaluation of the treatment program for mixed (hazardous/radioactive) wastes generated from metal finishing and plating operations at the Savannah River Site (SRS). With the elimination of virgin plutonium production, generation of nickel plating waste was eliminated. Therefore, only the wastewater treatment sludge stored from past plutonium target production in the Reactor Materials Department (M-Area) needs to be treated. A Life Cycle Cost (LCC) analysis determined that the stored waste could be treated much more cost effectively in a one-time campaign by a hazardous waste treatment sub-contractor than by constructing permanent on-site facilities to treat the waste.

The M-Area plating line sludge is a "listed" mixed (hazardous/radioactive) waste, containing depleted uranium. The sludge resulted from treatment of wastewater from nickel and aluminum cladding operations that prepared uranium targets for irradiation in the SRS reactors. Depleted uranium cores from Oak Ridge were etched, cleaned, nickel plated, clad in aluminum, inspected, and steam autoclave pressure tested. The targets were then transferred to the SRS reactors for irradiation, where the neutron flux in the reactors transmuted the uranium-238 to plutonium-239. The Pu-239 was separated from the uranium targets in the SRS "canyons" and transferred to other DOE sites for weapons production. In 1985, depleted uranium targets were being irradiated in four (4) SRS reactors, resulting in the generation of approximately 500,000 gallons of F006 plating line waste per year in M-Area.

The original program to treat the M-Area wastewater slurry was conceived in 1985, with the expectation that the slurry would be treated in an on-site hazardous waste treatment facility. The M-Area Waste Disposal Facility (designated "Y-Area") was designed to treat 1,200,000 gallons of waste per year, based on 500,000 gallons of plating line waste generation per year, and a 10 year work-off of the ~5,000,000 gallons of waste that would be stored in tanks by 1992. An additional 200,000 gallons/year of blowdown from the on-site Consolidated Incinerator Facility was also scheduled to be treated by Y-Area. The Y-Area Facility design was based on the design of the SRS cementatious facility (designated "Z-Area") to treat the low-level radioactive salt-supernate from the SRS saltcake storage tanks (waste from SRS canyons). The Z-Area facility uses a Portland cement/blast furnace slag/flyash mixture as a stabilizing agent for the salt-supernate, resulting in a grout mixture which is pumped to above ground radioactive disposal vaults. The salt-supernate is a mixed waste (radioactive/characteristically hazardous), but the final grout is non-hazardous, as the grout passes the Environmental Protection Agency's (EPA) Toxicity Characteristic Leaching Procedure (TCLP) for hazardous constituents.

SEPARATION AND TREATMENT OF THE SUPERNATE FROM THE M-AREA SLURRY

The waste slurry stored in the M-Area Interim Treatment/Storage Facility (IT/SF) tanks has spontaneously separated into a supernate and sludge (~25% by volume). It was demonstrated that the supernate could be treated in the close-coupled M-Area Dilute Effluent Treatment Facility (DETF) using metal phosphate precipitation and enhanced filtration methods. A modification to the industrial wastewater permit for the DETF was approved by the South Carolina Department of Health and Environmental Control (SCDHEC) and treatment of supernate began in May, 1990. This resulted in a 65-75% reduction of the final volume of hazardous waste that will have to be treated, stabilized, and disposed by hazardous waste treatment and disposal facilities.

TREATMENT AND DISPOSAL STUDIES ON M-AREA SLUDGE

DELISTING PETITION STUDY

A series of treatability studies were conducted by M-Area and the Savannah River Technology Center (SRTC) in 1988, to support a Delisting Petition for the stabilized sludge. The tests were conducted using sludge samples from the M-Area IT/SF tanks and the Y-Area process and stabilization materials. The final product was tested by both the EPA Extraction Procedure for Toxic wastes (EP Toxic) and the TCLP. The final wasteform did not meet the 0.32 mg/L nickel leachant criteria promulgated by the EPA as the Best Demonstrated Available Technology for F006 "listed" plating wastes (Table 1). None of the other constituents of concern for plating line sludges (Cd, Cr, Pb, Ag, or CN) were used in the M-Area plating operations.

Table 1. Initial Test Results for Delisting vs. EPA Land Ban Criteria.

Maximum For Any Single Grab Sample

Constituent	LDR Standard*	Delisting Petition - Tank 8 Sample Results	
	TCLP (mg/L)	TCLP (mg/L)	EP Toxic (mg/L)
Cd	0.066	<0.01	<0.01
Cr	5.2	<0.05	<0.05
Pb	0.51	<0.10	0.2 - 0.3
Ni	**0.32**	**0.030-0.81**	**1.2 - 2.0**
Ag	0.072	<0.01-0.04	<0.05

* LDR = Land Disposal Restrictions

SLUDGE PRETREATMENT (FILTRATION) AND STABILIZATION STUDY

Based on the results of the initial treatability study, a series of slurry filtration tests were conducted in November, 1988 and March, 1989. The objective of these filtration tests was to determine how to treat the concentrated wastewater slurry from continued production of depleted uranium targets in M-Area. Also, the sludge remaining in the IT/SF tanks after the supernate was decanted would be treated by the same filtration process. The pilot filtration program was expanded to include a number of formulation and stabilization tests to improve the leaching durability of the final wasteform, to demonstrate that the new Land Disposal Restriction regulations for hazardous waste leaching requirements could be met.

The tests demonstrated that pressure filtration of the slurry, followed by pressure washing/rinsing of the filtercake, reslurring with water, and mixing with the Y-Area dry solids mixture (or with Portland Type II cement) would produce a final stabilized wasteform which met the Land Ban Restrictions leaching criteria for nickel. A high (~6:1) ratio of cement/blast furnace slag/flyash (or just cement) vs. the total solids in the M-Area sludge was used. This resulted in a large volume increase (~3.3X) from sludge to the final wasteform.

The formulations and TCLP leaching results are summarized in Table 2. Only nickel, uranium, and nitrate were analyzed in the TCLP leachants, as the previous study had shown that the other F006 constituents would meet the BDAT criteria if nickel did.

Table 2. Sludge pretreatment formulations and TCLP leaching results.

Formulation	Formulation, Weight %			
	A	B	C	D
Sludge	6	6	6	6
BFS/FA/Cement*	52	47	-	-
Portland cement	-	-	52	47
NaOH	-	5	-	5
Water	42	42	42	42
	TCLP Leachant Concentration, mg/L**			
Nickel	<0.05 - 0.40	<0.05 - 0.21	<0.05	<0.05
Uranium	0.6 - 36	<0.2 - 16	<0.2	<0.2
Nitrate (as N)	0.5 - 3.0	0.4 - 3.2	0.2 - 1.4	0.5 - 2.6

*Blast Furnace Slag/Flyash/ Type II Portland Cement (45/45/10 dry wt.% ratio)
** Twelve separate tests for each formulation with different rinse volumes, with and with-out pre-neutralization of the sludge, and Ca, Mg, or Fe additives

These results indicated that <u>either</u> new M-Area sludge generated from on-going production, <u>or</u> the sludge from the IT/SF tanks could be washed, filtered, reslurried, and then shipped to and treated in the M-Area Waste Treatment Facility (Y-Area) to meet the LDR standard for nickel. Cement alone, with or without additional sodium hydroxide, achieved the lowest nickel and uranium leachant concentrations, but the BFS/FA/cement mixture with additional NaOH was acceptable.

STABILIZATION OF M-AREA SLUDGE USING CEMENT AND PRESSURE FILTRATION

A third treatability study was conducted by SRTC and M-Area in 1991. The objective was to determine if cement could be added directly to the sludge - prior to washing and pressure filtration - such that the final filtercake would meet the LDR restrictions without reslurring and additional processing. Scouting tests in the previous study had indicated that this approach could also provide substantial volume reduction of the final wasteform.

The sludge feed for the filtration tests was prepared by adding Portland Type II cement to the sludge, at a ratio of 1 gm cement to 4 gm total suspended solids (TSS). The sludge density was 1.24 gm/cc, with a TSS of 24 wt.%. The weight of the dissolved sodium nitrate (~12 wt. %) was not considered, since most of this was removed during the filtration and cake washing operations. The cement/sludge mixture was filtered in a 0.45 ft^2 Filtra-Systems Verti-Press® pilot scale filter, at a feed pressure of 25 psig and a dewatering squeeze pressure of 105 psig. Water was added to the filter press, and again pressure filtered, to wash the cake. The results of the feed rates and filtration rates were used to determine the design specifications for a full scale filtration unit, with the capability to support continued production and work-off of the stored sludge. The following variables, and ranges, were evaluated:

• Weight ratio of cement to sludge solids	0, 0.13, 0.27, 0.40
• Volume ratio of wash water to slurry feed	0:1, 1:1, 2:1
• Use of cationic polymer (Praestol ® K110L)	0 to 18 mg/L
• Ratio of filter aid (Envirogard®) to sludge solids*	0, 0.13, 0.27
• Ratio of $Ca(OH)_2$ to sludge solids*	0, 0.13, 0.27

*without cement addition

The key test combinations and TCLP results are summarized in Table 3.

Table 3. Direct cement addition test conditions and leaching results.

	Conditions								
Test No	11	4	7	2	1	26	34	33	32
Feed volume, L	1	2	2	2	2	2	2	2	2
Wash volume, L	1	2	2	2	0	2	2	2	2
Sludge solids, gms	294	588	588	588	588	588	588	588	588
Cement, gms	0	79	157	236	157	157	0	0	0
Ratio, cement to solids	0	0.13	0.27	0.40	0.27	0.27	0	0	0
Polymer	Yes	Yes	Yes	Yes	Yes	No	Yes	Yes	Yes
Filter aid, gms	0	0	0	0	0	0	0	79	157
$Ca(OH)_2$, gms	0	0	0	0	0	0	157	79	0
Final filtercake vol., L	0.3	0.8	0.7	0.4	0.8	0.8	0.8	0.8	0.7
	TCLP Leach Results, mg/L								
Nickel	2.9	0.14	<0.05	0.18	0.14	<0.05	<0.05	0.08	0.63
Uranium	74	1.9	0.7	0.9	1.3	<0.02	11	31	22
Nitrate, (as N)	27	11	9.7	9.5	300	11	55	21	9
TCLP pH	6.0	8.2	9.3	8.7	8.2	9.6	9.0	9.1	7.0

The key conclusions from the direct cement addition, plus pressure filtration and cake washing, were:

- Cake washing is required to provide a nitrate level in the final leachant which would support a delisting petition (test No. 1, w/o rinsing, had 300 gm/L in the TCLP leachant).
- All of the tests using cement resulted in a nickel concentration of less than the LDR standard of 0.32 mg/L in the TCLP leachant.
- The lowest uranium leachant concentration (<0.02 mg/L) was observed without polymer.
- Uranium concentrations of ~1 mg/L were observed with cement and polymer.
- Uranium leachant concentrations were ~10X higher without cement (tests 32,33,34)
- The lowest nickel concentrations were highly correlated with the measured pH of the final TCLP leachant solution.
- All of the tests resulted in a final volume of approximately 1/2 (or less) of the original sludge volume.

M-AREA FILTRATION AND STABILIZATION FACILITY (FIST)

The second treatability study in 1989 had demonstrated that if the M-Area sludge were filtered, washed, and reslurried prior to transfer to the Y-Area facility, the final Y-Area product would meet the LDR requirements. The third study demonstrated that if cement were added directly to the sludge prior to filtration and washing, a filtercake could be produced which met the LDR requirements and did not require additional treatment.

Based on the results of the treatability studies, the functional design criteria were established for a FIltration and STabilization (FIST) facility in M-Area. The facility was to:

- Treat nickel plating sludge from continuing target production in M-Area and/or to treat the sludge from the IT/SF tanks remaining after supernate treatment. The filtered and washed filtercake could be either:
  1) Reslurried and transferred to the centralized Y-Area for final treatment and disposal, or
  2) Transferred directly to the on-site Hazardous Waste/Mixed Waste (HW/MW) disposal vaults.

The FIST facility was estimated to cost approximately $12 million in capital funds, and ~$2 million per year in operating costs.

VOLUME OF WASTE TO BE TREATED

In 1991, the Department of Energy-Savannah River (DOE-SR) directed WSRC to change the status of the Building 313-M Slug Production Process, the facility in which the nickel plating operations were conducted, from "standby" to "shutdown". The production of virgin Pu239 was not anticipated prior to the year 2000, if at all. The cessation of plutonium production was announced by the Bush administration a year later.

This meant that no new plating line sludge would be generated for treatment, and that only the stored sludge remaining after treatment of the supernate from the IT/SF tanks would have to be treated and stabilized. The total amount of sludge to be stabilized in 1995 was estimated to be approximately 720,000 gallons. This would result in a 72,000 gallon/year treatment rate, assuming a 10 year work off by Y-Area, or by the FIST direct filtercake process.

However, since the FIST facility would not be needed to support on-going operations in M-Area, and would only be needed to pretreat the stored sludge prior to shipping to Y-Area, the necessity for the FIST facility was questioned. A Life Cycle Cost (LCC) analysis was conducted by the WSRC Systems Engineering Department to determine the most cost effective approach to manage the stored F006 sludge.

LIFE CYCLE COST ANALYSIS FOR TREATMENT OF THE M-AREA SLUDGE

Three cases were studied:

A. The sludges were pretreated and reslurried in the M-Area FIST facility, shipped to Y-Area, stabilized with BFS/FA/Portland cement, and disposed in the Y-Area vaults. The volume of the final grout was assumed to be 2x the volume of the original sludge.
B. The sludges are pretreated <u>and</u> stabilized in the M-Area FIST facility, and then shipped to the HW/MW vaults for disposal. This case assumed a 50% volume reduction for the final wasteform vs. the initial sludge volume (75% reduction vs. case A), by adding Portland cement to the sludge prior to the high pressure filtration step. Disposal in the HW/MW vaults is more expensive on a per cubic foot basis (vs. the Y-Area vault), due to the higher cost of the HW/MW vaults ($ 6 million vs. $ 4 million) and a lower loading factor (drums or boxes vs. full pour of grout).
C. The third case assumed that a hazardous waste subcontractor would stabilize the sludge in M-Area, place in containers, and dispose in the HW/MW vaults. A 2X volume increase from sludge to final cementatious wasteform was assumed in this case.

RESULTS OF LIFE CYCLE COST STUDY

The Life Cycle and Present Worth Cost estimates for Case A included the capital and operating costs for the M-Area pretreatment facility, a prorated operating cost at Y-Area, and the capital cost for the Y-Area vaults. The estimated Life Cycle Cost saving of $20 million for Case B vs. Case A resulted from the lower volume of final waste (even including the higher cost of the HW/MW vaults and the lower loading factor vs. the Y-area vaults), and no operating cost for Y-Area to treat M-Area sludge. The contractor option (Case C) indicated a significant opportunity for an additional $20 million cost saving (vs. case B). The cost saving for this option resulted primarily from eliminating the capital cost for the pretreatment facility in M-Area ($12 million) and eliminating the operating costs for the pretreatment facility over the 10 year work-off period ($2.4 million/year). The total estimated cost saving for the contractor option vs. the Y-Area option was $40 million.

Based on this cost study, WSRC recommended to the DOE-SR that the contractor option be selected, that design and construction of the pretreatment (FIST) facility be canceled, and that the M-Area wastes not be shipped to and treated/disposed in Y-Area.

The results of the M-Area LCC cost study are summarized in Table 4.

Table 4. Case descriptions and LCC and PW costs.

Case	A	B	C
	Pretreat in M-Area, stabilize & dispose in Y-Area vaults	Pretreat and stabilize in M-Area; dispose to HW/MW vaults	Contractor stabilize in M-Area; dispose to HW/MW vaults
	Costs, $ x 10^6		
Capital			
M-Area	10	12	-
Y-Area*	1	-	-
Trucks	2	-	-
Start-up **	1.6	1.1	
10 year operating			
Y-Area***	20	-	-
M-Area	18	24	-
10 year vault space (including boxes)	4.3	2.3	12
Contractor fee (at $8.80/gal)	-	-	6.3
Contractor Project administration	-	-	2.2
Clean closure of all IT/SF tanks	-	-	2.5
Life Cycle Cost (LCC)	67.7	46.4	28.2
Present Worth (PW) Cost	53.6	37.7	22.0

* incremental capital costs for storage tanks in Y-Area
** includes partial Y-Area start-up costs
*** 25% of Y-area annual operating costs, based on relative volume of M-Area sludge to CIF blowdown

Life Cycle Cost Analysis Procedure

Assumptions. The following assumptions were used:

- 720,000 gallons of sludge to be treated
- HW/MW vaults cost $6 million each
- HW/MW vaults will hold 9000, 55 gal. (or 71 gal. square) drums each, (85,000 cu. ft.), or
- HW/MW vaults will hold 1200 B-25's (90 cu. ft./B-25 = 108,000 cu. ft.)
- Y-Area vaults cost $4 million each, with capacity of 180,000 cu. ft.
- Average labor rate = $44.50/hr.
- Start-up costs = 25% of 1st year operating cost + 5% of capital cost.
- Life cycle and present worth costs based on 10 year operating life, with no salvage value.
- The economic analysis is intended to compare the relative costs of the different cases, and is not intended to be a definitive cost estimate of the actual life cycle cost.
- Final wasteform(s) will meet the Land Disposal Restrictions TCLP leaching criteria.
- Stabilization of the sludge by cementatious stabilization will result in 2X volume increase.
- Wastewater treatment will provide effluents which will meet NPDES permit requirements.

Economic evaluation analysis method. The Life Cycle Cost (LCC) and Present Worth (PW) were calculated using the following definitions and formulae (1, 2):

- LCC estimating is anticipated costs directly and indirectly related to preoperational, operational, and terminal stages.
- PW is a discounted dollar value, based on a technique of converting various cash flows occurring over a long period of time to equivalent amounts at a common point in time -- to facilitate a valid comparison.

$$LCC = (CC + SU) + (ECF * Y) + (ECF * Q)$$

$$PW = (CC + SU) + \left(Y * \left\{ \left[\frac{(1+i)^{N}-1}{(i \times (1+i)^{N})} \right] + D \right\} \right) + Q * \left(Y \times \left\{ \left[\frac{(1+i)^{N}-1}{(i \times (1+i)^{N})} \right] + E \right\} \right)$$

CC	=	Capital Cost
SU	=	Start-Up cost
ECF	=	Escalated Cost Factor for 10 years = 12.6
Y	=	Yearly operating cost
D	=	Operating cost escalation gradient factor, over 10 years (1.58)
N	=	Number of operating years (10)
i	=	Discount rate (5%)
Q	=	Annual Vault cost
E	=	Vault cost escalation gradient factor, over 10 years (1.31)

The PW calculation is primarily based on the initial capital investment and startup costs of the facilities, while the LCC reflects the escalated costs for the continuing capital expenditures for disposal vaults and continuing operating expenses. It is the authors' opinion that the LCC analysis provides a better comparison of the relative long term costs of the three cases than does the PW calculation.

LAND DISPOSAL RESTRICTIONS - FEDERAL FACILITIES COMPLIANCE AGREEMENT (LDR-FFCA)

There was another hurdle to be overcome before the new contractor option could be implemented. The M-Area sludge is a RCRA listed waste and a portion of the sludge was a "California List" waste, since it had been "actively managed" after July 1987, and had a concentration of >134 mg/L of nickel in the liquid from the sludge. The DOE-SR and WSRC had negotiated a Land Disposal Restrictions - Federal Facilities Compliance Agreement (LDR-FFCA) with the Environmental Protection Agency-Region IV in January 1991. The LDR-FFCA between the DOE and the EPA specified a number of activities which would be conducted by specific dates. The specific activities included submission of complete permit applications for Y-Area facility and the M-Area Pretreatment Facility. Construction of both facilities within specific time periods after the permits were approved was specified in the FFCA, and treatment goals were to be defined when operations commenced. The existing LDR-FFCA therefore had to be modified to remove the Y-Area and M-Area Pretreatment facility permit and construction deadlines, and replace them with new goals for the vendor treatment. The EPA approved the LDR-FFCA modification request in April 1992, primarily because the new vendor treatment approach allowed the treatment of the M-Area sludge to start about one year sooner than the original Pretreatment plus Y-Area concept (Case A), and treatment of the M-Area sludge would be completed approximately ten years sooner.

SUMMARY

With the end of the plutonium target production at the Savannah River Site, the need for an on-going facility to treat newly generated and/or stored mixed waste sludge was re-evaluated. A Life Cycle Cost analysis indicated that an estimated saving of $40 million could be realized by eliminating the Pretreatment (FIST) facility and having the waste treated and stabilized by a hazardous waste sub-contractor in a one time campaign. The sub-contractor is to mobilize the equipment and personnel on site, treat and stabilize the waste, and place it in seventy-one gallon square drums (or equivalent). The drums will be transferred to WSRC, who will provide interim storage and final disposal. The contractor will be responsible for certifying that the final waste meets the WSRC waste acceptance criteria, and reworking any waste that does not. WSRC has specified acceptance criteria which should allow a delisting petition to be approved by the EPA. WSRC will be responsible for the sample analysis, preparation, and submission of the delisting petition. If the delisting petition is approved by the EPA, this will allow the disposal of the stabilized waste to Low Level Radioactive disposal vaults, rather the much more expensive RCRA hazardous waste disposal vaults.

This change in the SRS program to treat and dispose of hazardous/radioactive wastes at the Savannah River Site exemplifies the commitment of the Westinghouse Savannah River Co. to provide the most cost effective management possible for the DOE challenges of the 90's.

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