LOW TEMPERATURE THERMAL SEPARATION OF HAZARDOUS COMPONENTS FROM Y-12 PLANT MIXED WASTE SOILS

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ABSTRACT

Chem-Nuclear Systems, Inc. (Chem-Nuclear) has completed its second treatability project for Martin Marietta Energy Systems, Inc. (Energy Systems) to demonstrate treatment processes for decontaminating mixed (hazardous and radioactive) waste soils generated at the Department of Energy's Y-12 Plant located in Oak Ridge, Tennessee. An earlier project was completed in 1988. The second project, conducted in 1989, involved two types of soils. Type 1 soil is characterized as dewatered, mercury and uranium contaminated sewer sediment and Type 2 is characterized as PCB, organics and uranium contaminated Oil Landfarm soil. Other metals, organics and oils and greases were also present in the samples tested.

Chem-Nuclear has performed a treatability evaluation on these two waste types utilizing treatment methods for the separation of chemical contaminants from the radioactive components. The performance goals for the treatment studies were to produce soil containing < 2 mg/kg (ppm) PCB and < 12 mg/kg mercury to achieve the Y-12 Plant disposal acceptance criteria. This paper presents a summary description of the recommended process, the recently patented X*TRAX^{TM} low temperature thermal separation system and a summary of the data obtained as a result of the second project. The data have been evaluated for success of achieving target contaminant removal in addition to feasibility of the recommended treatment method for a full-scale operation.

In the X*TRAX^{TM} process, the contaminated solids are heated in an indirectly fired rotary dryer to volatilize the organics. The vapors are carried to a gas handling system with an inert gas where they are scrubbed for particulates and cooled to condense the organics. The carrier gas is reheated and recycled to the dryer. The organics are sent off-site for disposal or incineration. The X*TRAX^{TM} system can handle a wide range of organics from high boiling compounds, such as PCBs, to low boiling compounds, such as RCRA regulated solvents. The full scale X*TRAX^{TM} Model 200 is also briefly described.

BACKGROUND

The widespread problem of soils and solids that are contaminated with PCBs and other organic chemicals, coupled with the EPA's ban on PCBs and other organics in landfills has resulted in the unavoidable fact that millions of cubic yards of material will have to be treated to reduce or eliminate the PCBs and other organics. Historically, the most likely treatment alternative has been high temperature incineration, which is very costly, difficult to obtain all required permits, and requires lengthy mobilization periods for system installation and trial burns. Low temperature thermal separation has been demonstrated to be a viable treatment option with significant advantages. This method of treatment can be applied to a broad class of waste materials that have relatively low PCB and organic concentrations - typically less than 10%. (1)

In the X*TRAX^{TM} process, contaminated solids are heated in an indirectly fired rotary dryer to volatilize the organics and moisture content. The vapors are carried to a gas handling system with nitrogen where they are scrubbed for particulates and cooled to condense the organics. The nitrogen carrier gas is reheated and recycled to the dryer. The recovered organics can be sent off-site for incineration or other suitable treatment/disposal options. The X*TRAX^{TM} system can handle soils and dewatered solids such as pond sludge and filter cakes. Organic contaminants can range from high boiling, semi-volatile compounds such as PCBs, to low boiling, volatile compounds such as RCRA regulated solvents. In September, 1989, the X*TRAX^{TM} process was granted a U.S. Patent.

Since January 1988, Chemical Waste Management, Inc. (CWM), Chem-Nuclear's parent company, has been operating a 1-3 kg/hr laboratory scale X*TRAX^{TM} system and a 4,500 kg (5 ton)/day mobile pilot system on both simulated and actual hazardous wastes including both Toxic Substances Control Act (TSCA) regulated PCB wastes and Resource Conservation and Recovery Act (RCRA) regulated materials. The results of this testing have confirmed the applicability of the process for contaminated soils and, to a lesser extent, for dewatered solids. Also, the data gathered from both of these systems has been used to design and construct the X*TRAX™ Model 200, a fully transportable production system capable of treating 113,400 kg (125 ton)/day of soil at 20% moisture content. The treatment rate is a direct function of the moisture in the feed. (1)

Since late 1988, Chem-Nuclear Systems, Inc. (Chem-Nuclear) , with CWM support, has conducted two mixed waste separation demonstra- tions for Department of Energy (DOE) Oak Ridge facilities. The first X*TRAX™ demonstration was conducted using the two trailer 4,500 kg/day mobile pilot unit at the Oak Ridge Gaseous Diffusion Plant (ORGDP) in July and August 1988.

As a result of the treatment of a variety of Y-12 Plant liquid process waste streams prior to discharge, a significant quantity of mixed waste sludge has been generated since mid-FY-1984. The primary sludge used in the demonstration was produced at the ORGDP K-1232 facility, which had been converted to carry out the interim treatment of Y-12 wastewaters formerly discharged to the Y-12, S-3 seepage ponds. When the new Central Pollution Control Facility (CPCF) at the Y-12 Plant achieved the capability of performing the wastewater treatment, the waste streams were re-routed from K-1232 to the new facility. Sludges from both K-1232 and the CPCF were processed in the demonstration. (2)

The sludges used in the 1988 demonstration are RCRA hazardous wastes, and are contaminated with uranium depleted in the 235 isotope, with trace quantities of other radioisotopes. These sludges are classified as a mixed waste. The RCRA designation for the sludges is F006, i.e., sludges resulting from the treatment of waste waters from electroplating operations. The hazardous organic constituents in the K-1232 sludge were successfully separated through X*TRAX™ processing, while the very high oil and grease content of the CPCF sludge (greater than 10%) caused plugging of the condensers. Design modifications would be required to accommodate the CPCF sludge characteristics which were outside the original X*TRAX™ demonstration scope of work.

The second mixed waste separation demonstration was conducted in October and November, 1989 using the 1-3 kg/hr laboratory scale X*TRAX™ system installed at Chem-Nuclear's Waste Management Facility in Barnwell, SC. Single drums of each of the Y-12 Plant Type 1 and Type 2 soils were used for the demonstration under South Carolina Department of Environmental Control permits. Type 1 waste soil is characterized as mercury, uranium and thorium contaminated, dewatered, sewer sediment and Type 2 waste soil is characterized as PCB/organics and uranium contaminated Oil Landfarm soil.

X*TRAX™ LABORATORY UNIT OPERATION

The X*TRAX™ process is a low temperature thermal separation unit that operates by heating contaminated soil to 204-427°C (400-800°F) in an externally heated rotary dryer, through which a nitrogen carrier gas is passed. The laboratory system is a mobile unit requiring a 20 foot by 15 foot processing area. A liquid nitrogen dewar is located near the processing area for carrier gas supply to the dryer.

The soil is fed to the rotary drum dryer via a feed hopper equipped with an electrical screw auger. The soil is placed into the hopper through the top opening. The opening is then covered with a lid which is equipped with a vent line for removal of volatiles. The feed rate is adjusted by controlling the rotational speed of the screw auger.

A basic process flow diagram for the X*TRAX™ pilot is shown in Fig. 1. The laboratory unit has a capacity to process from one to three kilograms of material per hour, depending on the

X*TRAX™: PROCESS FLOW DIAGRAM

residence time desired. Contaminated soils/sludges are fed into the dryer where they are heated to temperatures appropriate for the target organics and other vlatile constituents. The heat treated residues are discharged as a dry solid. The volatilized materials are removed by the nitrogen carrier gas to the gas handling system.

The nitrogen carrier gas containing the volatilized materials is treated in a three phase cooling and condensing train to remove the organic materials. Treatment begins when the carrier gas exits the drier and enters the spray tower. In the spray tower, the gas undergoes adiabatic cooling where essentially all of the particulate carryover is removed along with some of the low boiling point organics. The cooled nitrogen carrier gas, saturated with water vapor, is further cooled in the primary condenser which is a shell and tube heat exchanger. This water-cooled heat exchanger condenses a large portion of the water vapor along with some of the intermediate and low volatile organic compounds. The carrier gas is cooled again in the refrigerated secondary condenser which is another shell and tube heat exchanger. This action removes almost all of the remaining organics and most of the remaining water vapor.

Finally, the nitrogen carrier gas is passed through two 55 gallon carbon absorption filter drums for removal of any remaining organic and mercury constituents, a HEPA filter, and is then mixed with air before being vented to the atmosphere. The vented gases included primarily nitrogen, water, oxygen and non-detectable levels of organics and mercury.

The condensed water, mercury and organics in the spray tower are gravity separated into solids, organics and aqueous layers in the phase separator. The water portion from the phase separator can be reused for cooling in the spray tower. The condensate from the primary and secondary condensers are collected in condensate traps, one for

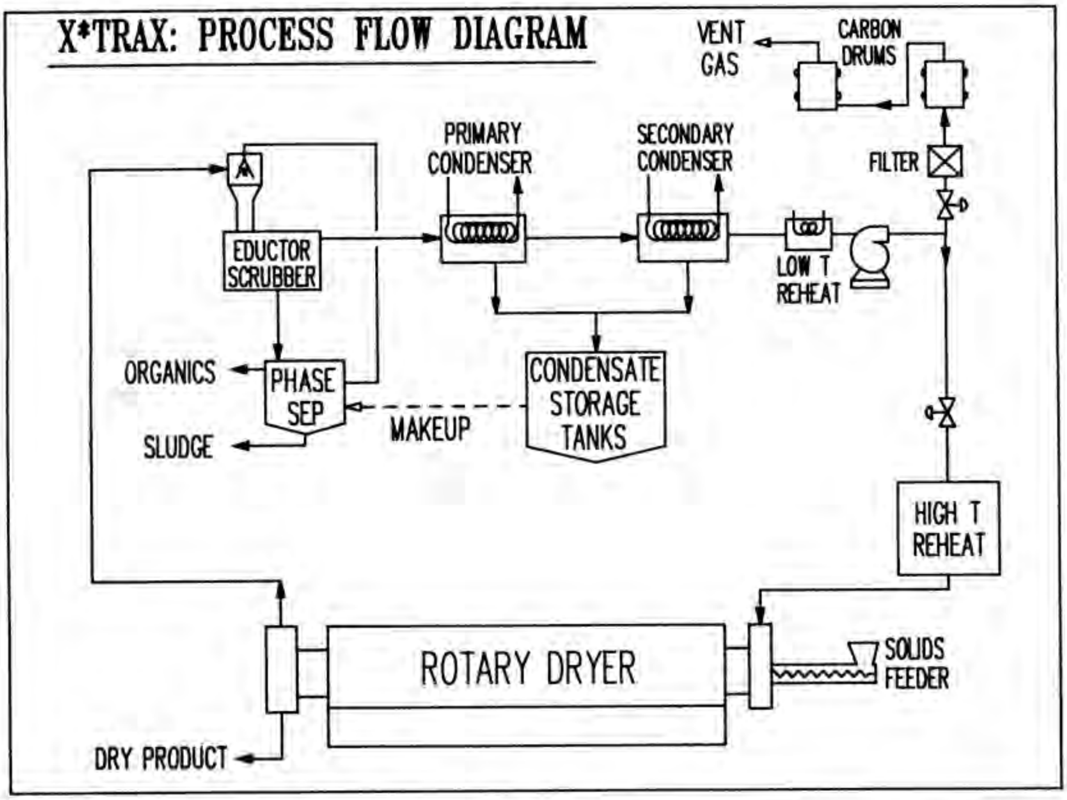

Fig. 1. X*TRAX: Process Flow Diagram.

each condenser. The product and treatment residuals are collected periodically throughout each processing run, and analyzed for target organics, RCRA metals, and radionuclides.

The pilot scale X*TRAX™ unit is identical in operation to the lab scale unit used in the treatability testing, with two exceptions. First, the nitrogen carrier gas is recycled to the dryer instead of being released to the atmosphere. A small portion (5-10% of the gas stream) is released through carbon adsorbers to prevent buildup of oxygen. Second, the dryer is externally heated using propane gas rather than electric resistance heaters.

The X*TRAX™ Model 200 is a full scale production system that has been constructed for onsite cleanup of contaminated soil. The system is capable of treating 125 tons per day of contaminated soil with a moisture content of 20%. Like the pilot system, the Model 200 has a rotary dryer and a gas treatment system; however, they are much larger, requiring the use of modular construction techniques. The Model 200 is fully transportable, consisting of three semi-trailers, one control room trailer, eight equipment skids and various pieces of removable equipment. The area required for the equipment layout measures about 120 ft. by 120 ft.

SUMMARY RESULTS

In the treatment of Y-12 Plant mixed waste soils, all treatment criteria including the removal of PCBs to less than 2 mg/kg were achieved in the six process runs for Type 2 Oil Landfarm soil. The first four runs on the Type 2 soil were performed to establish optimum operating parameters to achieve acceptable contaminant removal results. The next two runs were performed at the optimum conditions and confirmed with 90% confidence PCB removal to less than 1 mg/kg. (3)

Only one treatment run for Type 1 soil was conducted due to the premature condensation of mercury in the laboratory scale unit. Run 7 was conducted at previously established optimum conditions for PCB/organics removal which coincided with successful oven test parameters for mercury volatilization. Oven tests confirmed that mercury removal efficiency is responsive to temperature change but not to residence time variations. Run 7 achieved close-to-target results in the removal of mercury, 23 mg/kg, thus indicating that high removal efficiencies for both mercury and organics are achievable with equipment modifications.

Although soil washing demonstrations for mercury removal from Type 1 waste and PCB removal from Type 2 waste were conducted with some success, (generally 70-80% removal) the projected generation rates of secondary waste streams and the capital-intensive nature of these proposed processes make further pursuit of these alternatives unlikely.

SUMMARY OF ANALYTICAL RESULTS

This section presents a summary of the analytical data collected during the X*TRAX™ treatment evaluation. Since the first four runs established operating parameters, data presented in Table I represents results from runs 5 and 6 for Type 2 Oil Landfarm soil. Table II represents results from run 7 for Type 1 mercury contaminated sewer sediment.

TABLE I
Type 2 Oil Landfarm Soil
(mg/kg) Unless Noted)

Constituent	Feed	Run 5 Soil	Run 6 Soil
PCBs	14.9.	0.43	< 0.1
Mercury	.45	< 0.02	< 0.02
pH	----	6.80	7.00
Ash (percent)	----	95.6	94.7
Gross Alpha (pCi/gm)	51 to 99	86	66
Gross Beta (pCi/gm)	64 to 87	81	110
Oil & Grease Approx. by weight	1%	2700	1700

For the Type 2 soil, the analysis of the treated product shows an average percent removal of PCBs of 97.4. The volatile and semi-volatile organic analysis data indicates the presence of phenol, (bp 181.8°C) p-cresol, (bp 201.9°C) 2,4-dimethylphenol (bp 210°C) and naphthene (bp 217.7°C) in measurable ugm/kg (ppb) quantities in the treated soil. The condensate and phase separator liquid analysis show less than 5 pCi/l of alpha and beta activity. In accordance with the design of the X*TRAX™ system, the volatile organic constituents collected predominantly in the condensate samples and the semi-volatiles and PCBs collected in the phase separator. It is interesting to note that any measurable quantities of mercury appeared in the condensate liquid. This provided an indication of where the mercury would condense for the Type 1 soil treatment.

Table II presents the analytical results of the X*TRAX™ treatment operation for the Type 1 mercury contaminated sewer sediment. The percent mercury removal for Run 7 was 98.2 and the PCB percent removal was 97.6. The condensate liquid was reported as containing less

TABLE II
Type 1 Mercury Contaminated Sewer Sediment
(mg/kg) Unless Noted)

Constituent	Feed	Run 7 Soil	Phase Separator Liquid (1)
Mercury	1000 to 1300	23	.7 (mg/l)
Total Solids	----	1.00 E + 06	1100
PCBs	10 to 12.2	.29	< .1 (mg/l)
pH	----	8.5	7.5
Ash (percent)	----	98.5	----
Gross Alpha (pCi/gm)	86	55	140 (pCi/1)
Gross Beta (pCi/gm)	250	110	160 (pCi/1)
Oil & Grease Approx.by weight	1%	< 550	32 (mg/l)

(1) Figures do not represent the mercury-bearing solid particulate which collected in the phase separator. Analysis of these solids is not yet complete.

than 5 pCi/l of alpha and beta activity; however, the phase separator data indicated 140 and 160 pCi/l of alpha and beta activity, respectively. This high activity in the phase separator is most probably a result of the high particulate quantity that was observed in the phase separator. The volatile and semi-volatile organic analysis data indicates the presence of phenol, p-cresol, o-cresol (bp 190.8°C), 2,4-dimethylphenol, benzene (bp 80.1°C), styrene (bp 145°C) acetophenone (bp 202°C) and benzoic acid (bp 133°C) in measurable ugm/kg quantities in the treated soil. As previously noted, the volatile mercury, which condensed to the liquid phase, was collected in the condensate sample.

CONCLUSIONS

This report summarizes the results of Chem-Nuclear's treatability study which was performed to determine the feasibility of the proposed low temperature thermal separation treatment technology. The following removal efficiencies of the target contaminants were determined for X*TRAX™ processing:

TYPE 1 WASTE, MERCURY CONTAMINATED SEWER SEDIMENT

98.2% Mercury Removal

97.6% PCB Removal

TYPE 2 WASTE, OIL LANDFARM SOIL

97.4% PCB Removal

The X*TRAX™ treatment of the Type 2 Oil Landfarm soil proved very successful in removing the PCBs and other organic constituents present. The average PCB concentration in the treated soil was 0.39 mg/kg. The condensate and phase separator liquids both contained less than 0.0005 mCi/m^3 of activity.

The X*TRAX™ treatment of the Type 1 mercury sewer sediment indicated that treatment of high mercury content soils is feasible, although the treated sediment mercury content was 23 mg/kg, which is above the 12 mg/kg criteria, for the single run completed. Some equipment modifications would be required to the gas handling system in order to collect the mercury in one segment of the process. Other modifications are required to reduce particulate carryover from the dryer effluent. The 10 to 12.2 mg/kg PCBs were removed to a level of 0.29 mg/kg in the Type 1 sediment.

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