Treatment and Stabilization of Potentially Pyrophoric Radioactive Metal Chips and Turnings

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ABSTRACT

As part of the continuing mission to decontaminate, decommission, and restore environmental quality at multiple sites throughout the U.S. Department of Energy (US DOE) nuclear complex, approximately 2,000 containers of potentially pyrophoric radioactive metal chips and turnings, weighing over 192,000 kilograms have been identified. These wastes, mostly depleted uranium (DU) and thorium metals, must be treated to remove or immobilize a wide range of hazardous and toxic regulated waste constituents without igniting the radioactive metal. Also, the treated metal wastes must be placed in an inert condition to prevent any future pyrophoric problems during storage, transportation, and disposal. All secondary wastes resulting from treatment activities must have a pathway to final disposal or destruction, in accordance with all applicable US federal and state laws, and regulations.

To further this mission and to begin reducing the pyrophoric radioactive metal inventories throughout the US DOE system, a contract was awarded to Perma-Fix Environmental Services, Inc. to develop appropriate treatment methods, prove those methods in a First Article Test (FAT), and treat US DOE's existing inventory of pyrophoric radioactive metal wastes. The FAT was performed successfully between October 2002 and December 2002 using four containers of waste from the Rocky Flats Environmental Technology Site. The treated chips and turnings from this FAT were shipped for disposal at a private land disposal facility in the State of Utah. Since the FAT, two full-scale treatment projects have been performed under the contract. Between November 6, 2003 and March 4, 2004, 478 containers of Hanford DU chip wastes in mineral oil and soil matrices were treated. The treated chip waste was returned for disposal at the permitted mixed waste landfill at the Hanford Site. Between February 5, 2004, and February 25, 2005, another 222 containers of Rocky Flats DU chip waste, comprised of three distinct physical waste forms, were treated and disposed at the same land disposal facility in Utah.

Complicating this task was the wide variety of hazardous and toxic contaminants, and great variability in the physical waste form. The chemical contaminants included mineral oil, polychlorinated biphenyls (PCBs), numerous volatile and semi-volatile organic contaminants, and toxic metals. Three main physical waste forms were included in the US DOE pyrophoric radioactive metal waste inventory: (1) chips and turnings in oil, (2) chips and turnings in soil, and (3) chips and turnings in sludge. The successful treatment method had to be capable of removing oil, PCBs, and volatile organics without resulting in ignition of the pyrophoric metals. After successful removal of hazardous and toxic organic contaminants, the toxic metals remaining in the waste required further stabilization to limit their potential for long-term leaching in land disposal facilities. The final waste form and its packaging also had to comply with the waste acceptance criteria of the land disposal facilities at the US DOE Hanford Site, in Richland, Washington, and the private disposal facility in Utah.

This paper will describe the treatment process, the challenges encountered and overcome, the lessons learned, and final quality of the treated chip waste. Disposal and/or destruction of secondary wastes from the treatment process will also be discussed.

INTRODUCTION

Throughout the approximately 65 years of US DOE operations at multiple research and production sites in the United States, a legacy of reactive radioactive metal wastes has been accumulated. Much of this waste was packaged in steel drums and buried in trenches at the sites where the waste was generated. Since the late 1980s, US DOE has been working to remove buried waste, treat it to appropriate treatment standards, and dispose of it in properly-constructed and regulated land disposal facilities.

As part of this continuing mission, approximately 2,000 containers of potentially pyrophoric radioactive metal chips and turnings, weighing over 192,000 kilograms have been identified. These wastes primarily consist of uranium and thorium metals in the form of metal chips and turnings. Because of the high ratios of surface area to mass and the natural reactivity of these metals, the waste has the potential to behave in a pyrophoric manner, when exposed to air or water. To protect against this propensity for ignition, the waste was often packaged in mineral oil, soil, or sludge-like materials. Unfortunately, these waste forms also contained regulated volatile and semi-volatile organic compounds and polychlorinated biphenyls (PCBs). Table I provides a summary of the hazardous chemical constituents and the land disposal limits applicable to each under the "Universal Treatment Standard."

The chemical hazards described in Table I caused this waste to be restricted from land disposal in its un-treated condition. US DOE needed a contractor to safely treat the waste to reduce the concentration of each regulated parameter below its respective land disposal limit. To be successful, the contractor would have to remove, immobilize, and/or destroy the hazardous chemical constituents while preventing ignition of the air and water reactive metals comprising the solid waste matrix. Perma-Fix Environmental Services, Inc. won a competitive bid to perform these waste treatment services, beginning with a small First Article Test and if successful, to proceed with full-scale treatment. The scope of services included separation, treatment, sampling, analysis and shipment for disposal of the treated primary waste, and for any secondary waste solids or liquids derived from the primary waste.

The FAT and all full-scale operations were performed at the Materials & Energy Corporation facility in Oak Ridge, Tennessee. This facility provides commercial mixed waste and radioactive waste treatment services to private and governmental organizations throughout the United States.

The facility is authorized to perform hazardous waste treatment under a Hazardous Waste Management Permit issued by the Tennessee Department of Energy and Conservation (TDEC), Division of Solid Waste. The facility's authorization to possess and manage radioactive materials comes from a Radioactive Materials License issued by the Division of Radiological Health (DRH) of TDEC, under an agreement with the US Nuclear Regulatory Commission.

The safety and health hazards of this project in descending order of importance were: (1) the pyrophoricity hazard, (2) the toxicity of chemical contaminants, (3) the water reactivity of the reactive metals, (4) the potential for radioactive particles to be inhaled or absorbed through the skin, and (5) the radiation dose to the exposed workers. All of these hazards were effectively managed throughout the FAT and full-scale production activities.

Table I. Summary of the Hazardous Chemical Constituents in the Pyrophoric Metal Waste (Reported in mg/Kg Unless Otherwise Noted)

Hazardous Chemical Constituents	**Rocky Flats Chips in Oil**	**Hanford Chips and Turnings**	**Land Disposal Limit (Universal Treatment Standard)**
Ignitable (D001)	Yes	Yes	Deactivation
Reactive (D003)	Yes	Yes	Deactivation
Acetone	NA	0.1 to 390	160.0
Benzene	NA	0.1 to 75	10.0
Carbon Tetrachloride	NA	0.1 to 78	6.0
Chloroform	NA	0.1 to 10	6.0
Cresols (o, m, p)	NA	0.1 to 1,000	11.2
p-Dichlorobenzene	NA	0.1 to 1,000	6.0
1,2-Dichloroethane	NA	0.1 to 78	6.0
1,1-Dichloroethylene	NA	0.1 to 78	6.0
2,4-Dimethylphenol	NA	0.1 to 35,000	14.0
2,4-Dinitrotoluene	NA	0.1 to 1,000	140.0
Ethyl benzene	NA	0.1 to 190	10.0
Hexachlorobenzene	NA	0.1 to 1,000	10.0
Hexachlorobutadiene	NA	0.1 to 1,000	5.6
Hexachloroethane	NA	0.1 to 1,000	30.0
Methylene chloride	NA	0.1 to 200	30.0
2-butanone	NA	0.1 to 1,900	36.0
Naphthalene	2.3 to 45	0.1 to 6,800	5.6
Nitrobenzene	NA	0.1 to 1,000	14.0
PCBs	0.1 to 2,200	0.1 to 560	10.0
Pentachlorophenol	NA	0.1 to 5,000	7.4
Phenanthrene	2.0 to 9.0	NA	5.6
Polynuclear Aromatic Hydrocarbons	NA	0.1 to 1,000	2.6 to 8.2
Tetrachloroethene	100 to 200,000	0.1 to 99	6.0
Toluene	NA	0.1 to 410	10.0
Trichloroethene	0.1 to 10,000	0.1 to 2,000	6.0
2,4,5-Trichlorophenol	NA	0.1 to 1,000	7.4
2,4,6-Trichlorophenol	NA	0.1 to 1,000	7.4
Vinyl chloride	NA	0.1 to 160	6.0
Xylenes	NA	0.1 to 1,200	30.0
Arsenic (mg/L in TCLP Extract)	NA	0.01 to 0.84	5.0
Barium (mg/L in TCLP Extract)	NA	0.1 to 1,170	21.0
Cadmium (mg/L in TCLP Extract)	0.1 to 2,270	0.1 to 0.29	0.11
Chromium (mg/L in TCLP Extract)	NA	0.1 to 1.6	0.60
Lead (mg/L in TCLP Extract)	NA	0.1 to 277	0.75
Mercury (mg/L in TCLP Extract)	NA	0.01 to 1.40	0.025
Selenium (mg/L in TCLP Extract)	NA	0.1 to 1.4	5.7
Silver (mg/L in TCLP Extract)	NA	0.1 to 0.98	0.14

PROCESS DEVELOPMENT AND PROOF OF PROCESS

The objectives for treatment of the reactive metal wastes were ambitious, as summarized below.

1. Effectively prevent ignition of the pyrophoric metals throughout the treatment process
2. Effectively remove regulated organic contaminants, leaving only residual concentrations less than the applicable Land Disposal Limits
3. Provide analytical proof that treatment standards had been met
4. Minimize the generation of solid and liquid secondary wastes derived from the primary waste
5. Manage all primary and secondary wastes in full compliance with applicable laws and regulations
6. Ship all waste materials to appropriate off-site disposal facilities and obtain certificates of compliant disposal for all wastes

A central concept of the treatment process was the idea that the solvent used to wash the organic contaminants out of the waste matrix should also be effective in excluding airborne oxygen from reactive metal surfaces. If the blanketing mineral oil were removed, and not replaced with a clean blanketing liquid, an ignition of the pyrophoric metal could occur. Also, a solvent with a flash point higher than 49 Degrees Celsius (120 Degrees F) would help to prevent solvent ignition. In addition to accomplishing these six objectives for all of the waste in the US DOE Inventory, the contract required that the treatment process be developed specifically for the waste, and proven in a First Article Test (FAT). Following a successful demonstration of the process in the FAT, the process could be enlarged in scale to better meet full-scale production goals. Following scale-up, the treatment of commercial quantities of waste from the various US DOE sites would be performed expeditiously.

FIRST ARTICLE TEST

The FAT was performed with four containers of DU chip wastes from the Rocky Flats Environmental Technology Site (Rocky Flats), beginning in October 2002. As shown in Table I, the Rocky Flats waste had fewer regulated chemical contaminants than the Hanford waste. The containers selected for the FAT included DU chips in mineral oil, and DU chips in a sludge matrix. Samples of each waste were rinsed using various commercially available solvents to evaluate solvent effectiveness in removing mineral oil and regulated contaminants. Tests were conducted using kerosene, mineral oil, n-hexane, mineral spirits, dipentene, and d-Limonene. The comparative results showed that dipentene and d-Limonene were the most effective solvents having a flash point over 49 Degrees Celsius.

In the process demonstration phase of the FAT, waste was transferred from the original containers into a steel treatment drum, modified with steel flights welded to the inside walls. This treatment drum was filled with waste from each incoming drum and fresh dipentene solvent. The drum lid was sealed in place, and provided with a venting arrangement. The treatment drum was laid on its side on an electric drum-rolling device. Using the drum-rolling device, the material in the drum was washed with the dipentene solvent for approximately one-half hour. Periodically, the vent valve was cycled to ensure that pressure did not build up in the treatment drum. The used solvent was decanted into a receiving drum. Fresh solvent was added to the treatment drum, and the washing procedure was repeated, a second time. At the conclusion of the second wash, the waste was transferred to a strainer basket inside a 208-Liter (55-gallon) drum. Three more washes were performed using a recirculating spray wash inside the strainer basket. At the completion of the fifth wash, the wash solvent was allowed to drain away. Samples of solids from each of the five washes were collected for laboratory analysis. This procedure was repeated for each of the four waste drums included in the FAT. Three of the four drums contained metal chips and turnings and mineral oil with only small quantities of fine material. The fourth container held a fine-grained oily sludge that contained few chips and turnings. Much of this waste had agglomerated into a large fused lump. The methods previously employed proved problematic, due to the difficulty of

breaking up the fused lump and the difficulty of separating fines from the wash liquids. Manual methods applied prior to removal of the blanketing oil were successful in breaking up the fused lumps. The test was completed with satisfactory results. As the FAT progressed, a water/detergent wash was implemented as the last wash step to help remove residual solvent from the solids. The solvent interfered with the analysis of semi-volatile organic contaminants necessary to document compliance with the treatment standards. The water/detergent wash helped minimize the analytical interferences.

The washed DU chips, turnings, and fines were solidified for disposal using a grout formulation designed to absorb and bind all residual liquids. This formulation also immobilized the cadmium contamination in the washed chips and turnings.

Analysis of the treated waste samples showed that the PCBs, tetrachloroethene, trichloroethene, and cadmium, in the treated waste were below the treatment standards, indicating the technical success of the demonstrated treatment process.

Some valuable lessons were learned from the FAT. The most important of these are listed below.

1. The solvents and wash solutions performed effectively as blanketing liquids, in preventing any ignition of the reactive metals.
2. The dipentene was an effective solvent for removing PCBs, tetrachloroethene, and trichloroethene.
3. The grouting method was effective in stabilizing cadmium and binding moisture.
4. A water/detergent wash was necessary to reduce the severity of analytical interferences with the semi-volatile organic compound analysis.
5. Although dipentene was effective, an effective solvent that was easier to wash out of the treated waste matrix would be beneficial to the full-scale treatment operation.
6. The drum rolling method of washing the chips and turnings was found to be effective but too slow to be useful in the full-scale operation.

SCALE UP OF THE PROCESS

Following the success of the FAT demonstration, M&EC optimized the process to make it useful for full-scale treatment. The lessons learned during the FAT became the basis for scale-up of the process for commercial treatment operations. M&EC continued evaluating solvents, hoping to identify a solvent as good, or better than dipentene, which would also be easier to wash out of the treated waste. The solvent also had to be free of government regulation as a hazardous waste. The process required a larger mixer, and preferably more than one of these larger mixers. A rotary drum concrete mixer was found to be the best mixer for full-scale operation. Also, solvents would be used in serial fashion a minimum of three times before being discarded to container storage as a secondary liquid waste. The cascading of solvents would be in reverse order, such that untreated chips were first washed with third-use solvent, then with second-use solvent, then by unused solvent, and finally by the hot water/detergent rinse. After use, each dirty solvent decanted from the mixer would be held in a steel drum to allow fines to settle to the bottom of the drum so relatively clear solvent liquids could be decanted from the settling drum into containers for use in the next wash, or for off-site incineration. Fines were bulked for later treatment by vacuum thermal desorption.

FULL SCALE PRODUCTION

Full-scale treatment of Hanford reactive metal wastes took place over a period of 81operational days between November 6, 2003 and March 4, 2004, in which 478 containers of waste were treated. Full-scale treatment of Rocky Flats reactive metal wastes took place over a period of 63 operational days, between

February 5, 2004 and January 10, 2005, in which 222 containers of waste were treated. In the full-scale operation, two rotary drum concrete mixers were used, with each drum having the capacity to hold and mix approximately 0.23 cubic meters of waste in each batch. These mixers were operated simultaneously, allowing daily production rates ranging from 0.9 to 1.3 cubic meters per day.

Midway during the full-scale operation a better solvent was found, and it was substituted for the dipentene. It was not a government-regulated solvent, it was more effective than dipentene, and it was much easier to wash out of the treated solids. Good miscibility with water also made it easier to blend for incineration. Because Perma-Fix considers the identity of this solvent to be proprietary, it cannot be named in this paper. However, we continue to investigate alternative solvents, hoping to gain even more solvent utility.

As full-scale production continued, M&EC observed that there were two different kinds of fines liberated in the process. DU fines behaved like the larger DU chips and turnings, but would be washed out of the coarser matrix in the decanting operation. These solids were found to settle quickly in the solids settling drums. Fines derived from soil and sludge were slower to settle and therefore, a separation was made between these two fines fractions. Settled DU fines were washed with the hot/water detergent and re-combined with the coarser materials they came from. Soil fines required a radical departure from the solvent/detergent washing method.

Because of the difficulty in separating the soil fines from the wash liquids, the mixture was pumped into the Perma-Fix II Vacuum Thermal Desorber, blanketed with inert gas, and treated in batch mode by vacuum thermal desorption. This process effectively vaporized the water and organic contaminants and recovered these in a vapor condensing and recovery system. Prior to discharging the dry residues from the desorber, water was added so that dust would be suppressed and oxygen would be excluded from any DU metal chips, turnings or particles present in the dry material. Since the final step of full-scale treatment was immobilization of metals using a grout formulation, the water added to the fines simply replaced the moisture requirements for hydration of the grout ingredients.

After laboratory analysis for each batch of washed chips, turnings, or fines showed that all regulated organic constituents were below the treatment standards, these solid materials were treated for metals immobilization and grouted to produce an inert solid monolith cast in its disposal container. Sampling of the grouted material confirmed that the toxic metal constituents had been immobilized, allowing compliant land disposal of the treated waste. The final solid waste forms resulting from the full-scale production of Rocky Flats DU waste were shipped to a commercial land disposal facility in Utah where they were buried in an above-grade engineered embankment disposal cell. The final solid waste forms from the Hanford DU waste were returned to Hanford for disposal in their on-site landfill.

Table I shows that the Hanford waste contained many more regulated contaminants than the Rocky Flats waste. The analytical burden of proof demonstrating compliance with the treatment standards was much greater for the Hanford project. The change of solvents was particularly important to providing proof of compliance. All of the organic and inorganic constituents regulated for these wastes were reduced to concentrations below the applicable treatment standards.

SECONDARY WASTES

A key to the success of the full-scale production campaign was in the ability of M&EC and Perma-Fix to handle, store, ship, and dispose of all of the myriad forms of secondary waste generated during these campaigns. Some of these secondary wastes were:

- Empty drums, overpack containers, and dunnage were decontaminated by washing, crushed, and packaged for burial with the treated primary wastes.
- Decanted mineral oil having a total PCB concentration less than 50 mg/Kg was combined in bulk containers and sent to another Perma-Fix facility for combustion.
- Used wash liquids having a total PCB concentration less than 50 mg/Kg were combined in bulk containers and sent to the same Perma-Fix facility for combustion.
- Decanted mineral oil, or used wash liquids exceeding a total PCB concentration of 50 mg/Kg were combined in bulk containers and sent to the US DOE Toxic Substances Control Act (TSCA) Incinerator in Oak Ridge, Tennessee for incineration.
- Process equipment was decontaminated and retained by M&EC for use in future treatment projects.
- Uncontaminated protective clothing was added to containers of treated waste to help fill void volume.
- Contaminated protective clothing was subjected to the same solvent and hot water/detergent washing as was used for the DU chips. After treatment, a moisture absorbent was added to ensure that the waste was free of separable liquids.

RESULTS OF TREATMENT

The data in Table I show that the Rocky Flats waste had fewer regulated contaminants than the Hanford Waste. Also, the physical form of the waste from Rocky Flats was significantly different. The DU in Soil and the DU in Sludge consisted mostly of fine grain particles, similar in appearance and behavior to fine clay. The solvent and hot water/detergent washing of the Rocky Flats waste was more like solvent extraction of fine-grained sludge. The efficiency of the wash/decant operation was impaired by the difficulty of settling the fine particles. The prescribed washes were performed and the decanting of wash liquids was effective enough to lower the total naphthalene, phenanthrene, PCB, and trichloroethene concentrations below the treatment standard value. However, tetrachloroethene concentrations were not sufficiently reduced by washing alone. The washed solids were treated in the Perma-Fix II Reactor to remove the rest of the tetrachloroethene. Table II compares the hazard characteristics of the Treated Rocky Flats waste with the untreated waste and the applicable treatment standards.

Although the Hanford waste was much more complex in its chemical hazards than the Rocky Flats Waste, the physical form of the Hanford Waste was more typical of DU chips and turnings. The portion of the waste consisting of fine grain materials was much less than that seen during the Rocky Flats campaign. The solvent and hot water/detergent washing of the Hanford waste was more effective than it had been for the Rocky Flats waste. Only small quantities of fine-grained material from the liquid decanting operation required treatment in the Perma-Fix II Vacuum Thermal Desorber. Table III compares the hazard characteristics of the treated Hanford waste with the untreated waste and the applicable treatment standards.

Throughout the FAT and both full-scale treatment campaigns, effective treatment was performed, without any ignitions of reactive metals or other health or safety mishaps.

Table II. Summary of Treated Waste Characteristics – Rocky Flats Waste (Units Reported in mg/Kg Unless Otherwise Noted)

Hazardous Characteristic	Untreated Rocky Flats Waste	Treated Rocky Flats Waste	Treatment Standard
Ignitable (D001)	Yes	Deactivated	Deactivated
Reactive (D003)	Yes	Deactivated	Deactivated
Naphthalene	2.3 to 45	0.04 to 4.99	5.6
PCBs	0.1 to 2,200	1.19 to 8.75	10.0
Phenanthrene	2.0 to 9.0	0.065 to 4.99	5.6
Tetrachloroethene	100 to 200,000	0.073 to 1.21	6.0
Trichloroethene	0.1 to 10,000	0.022 to 0.75	6.0
Cadmium (mg/L in TCLP Extract)	0.1 to 2,270	<0.11	0.11

CONCLUSIONS

The operating experience gained by M&EC and Perma-Fix during these treatment campaigns has shown that potentially pyrophoric metal chips and turnings can be treated to remove volatile and semi-volatile organic constituents, polychlorinated biphenyls, and mineral oil, without undue risk of igniting the reactive metal. A combination of solvent washing, hot water and detergent washing, and metals immobilization was employed to remove organic contaminants and immobilize toxic metals, making the treated DU chips and turnings compliant with land disposal treatment standards. Soil fines required vacuum thermal desorption after attempts to wash these fine solids proved to be only partially effective. M&EC and Perma-Fix will continue applying these treatment methods to similar types of waste in the future.

Table III. Summary of Pyrophoric Metal Waste Hazard Characteristics (Units Reported in mg/Kg Unless Otherwise Noted)

Hazardous Characteristic	Untreated Hanford Chips and Turnings	Treated Hanford Chips and Turnings	Treatment Standard
Ignitable (D001)	Yes	Deactivated	Deactivated
Reactive (D003)	Yes	Deactivated	Deactivated
Acetone	0.1 to 390	<4.97	160.0
Benzene	0.1 to 75	<4.97	10.0
Carbon Tetrachloride	0.1 to 78	<4.97	6.0
Chloroform	0.1 to 10	<4.97	6.0
Cresols (o, m, p)	0.1 to 1,000	<1.47	11.2
p-Dichlorobenzene	0.1 to 1,000	<5.59	6.0
1,2-Dichloroethane	0.1 to 78	<4.97	6.0
1,1-Dichloroethylene	0.1 to 78	<4.97	6.0
2,4-Dimethylphenol	0.1 to 35,000	<5.59	14.0
2,4-Dinitrotoluene	0.1 to 1,000	<5.59	140.0
Ethyl benzene	0.1 to 190	<4.97	10.0
Hexachlorobenzene	0.1 to 1,000	<5.59	10.0
Hexachlorobutadiene	0.1 to 1,000	<5.59	5.6
Hexachloroethane	0.1 to 1,000	<5.59	30.0
Methylene chloride	0.1 to 200	<4.97	30.0
2-butanone	0.1 to 1,900	<4.97	36.0
Naphthalene	0.1 to 6,800	<5.59	5.6
Nitrobenzene	0.1 to 1,000	<5.59	14.0
PCBs	0.1 to 560	1.14 to 6.35	10.0
Pentachlorophenol	0.1 to 5,000	<5.59	7.4
Phenanthrene	NA	<5.59	5.6
Polynuclear Aromatic Hydrocarbons	0.1 to 1,000	0.19 to 5.59 *	2.6 to 8.2
Tetrachloroethene	0.1 to 99	<4.97	6.0
Toluene	0.1 to 410	<4.97	10.0
Trichloroethene	0.1 to 2,000	<4.97	6.0
2,4,5-Trichlorophenol	0.1 to 1,000	<5.59	7.4
2,4,6-Trichlorophenol	0.1 to 1,000	<5.59	7.4
Vinyl chloride	0.1 to 160	<2.76	6.0
Xylenes	0.1 to 1,200	<10.5	30.0
Arsenic (mg/L in TCLP Extract)	0.01 to 0.84	0.05 to 2.88	5.0
Barium (mg/L in TCLP Extract)	0.1 to 1,170	0.157 to 0.909	21.0
Cadmium (mg/L in TCLP Extract)	0.1 to 0.29	0.0015 to 0.1036	0.11
Chromium (mg/L in TCLP Extract)	0.1 to 1.6	0.1018 to 0.488	0.60
Lead (mg/L in TCLP Extract)	0.1 to 277	0.0341 to 0.1362	0.75
Mercury (mg/L in TCLP Extract)	0.01 to 1.40	0.0020 to 0.00278	0.025
Selenium (mg/L in TCLP Extract)	0.1 to 1.4	0.050 to 0.426	5.7
Silver (mg/L in TCLP Extract)	0.1 to 0.98	0.05 to 0.791	0.14

**Each individual PAH was less than its specific Treatment Standard*